

NEOSHO RIVER BASIN TOTAL MAXIMUM DAILY LOAD

Water Body: Marion Lake (Marion Reservoir)

Water Quality Impairment: Eutrophication

Revision to TMDL Originally Approved, January 6, 2005

1. INTRODUCTION AND PROBLEM IDENTIFICATION

Subbasin:	Upper Cottonwood	Counties:	Marion and McPherson
HUC 8:	11070202	HUC 11 (HUC14):	010 (010, 020, 030, 040, 050)
Ecoregion:	Central Great Plains/Smoky Hills (27a) Central Great Plains/Wellington-McPherson Lowland (27d) Flint Hills (28)		
Drainage Area:	Approximately 204 square miles (Figure 1)		
Conservation Pool:	Area = 6,200 acres Watershed Area: Lake Surface Area = 20:1 Maximum Depth = 8.5 meters (28 feet) Mean Depth = 3.4 meters (11 feet) Retention Time = 2.2 years (26 months)		
Designated Uses:	Primary Contact Recreation; Expected Aquatic Life Support; Drinking Water; Industrial Water Supply Use; Food Procurement; Groundwater recharge Irrigation; Livestock Watering		
Authority:	Federal (U.S. Army Corps of Engineers), State (Kansas Water Office)		
2002 303(d) Listing:	Neosho Impaired Lakes		
Impaired Use:	All uses are impaired to a degree by eutrophication		
Water Quality Standard:	Nutrients - Narrative: The introduction of plant nutrients into streams, lakes, or wetlands from artificial sources shall be controlled to prevent the accelerated succession or replacement of aquatic biota or the production of undesirable quantities or kinds of aquatic life (KAR 28-16-28e(c)(2)(A)). The introduction of plant nutrients into surface waters designated for primary or secondary contact recreational use shall be controlled to prevent the development of objectionable concentrations of algae or algal by-products or nuisance growths of submersed, floating, or emergent aquatic vegetation (KAR 28-16-28e(c)(7)(A)).		

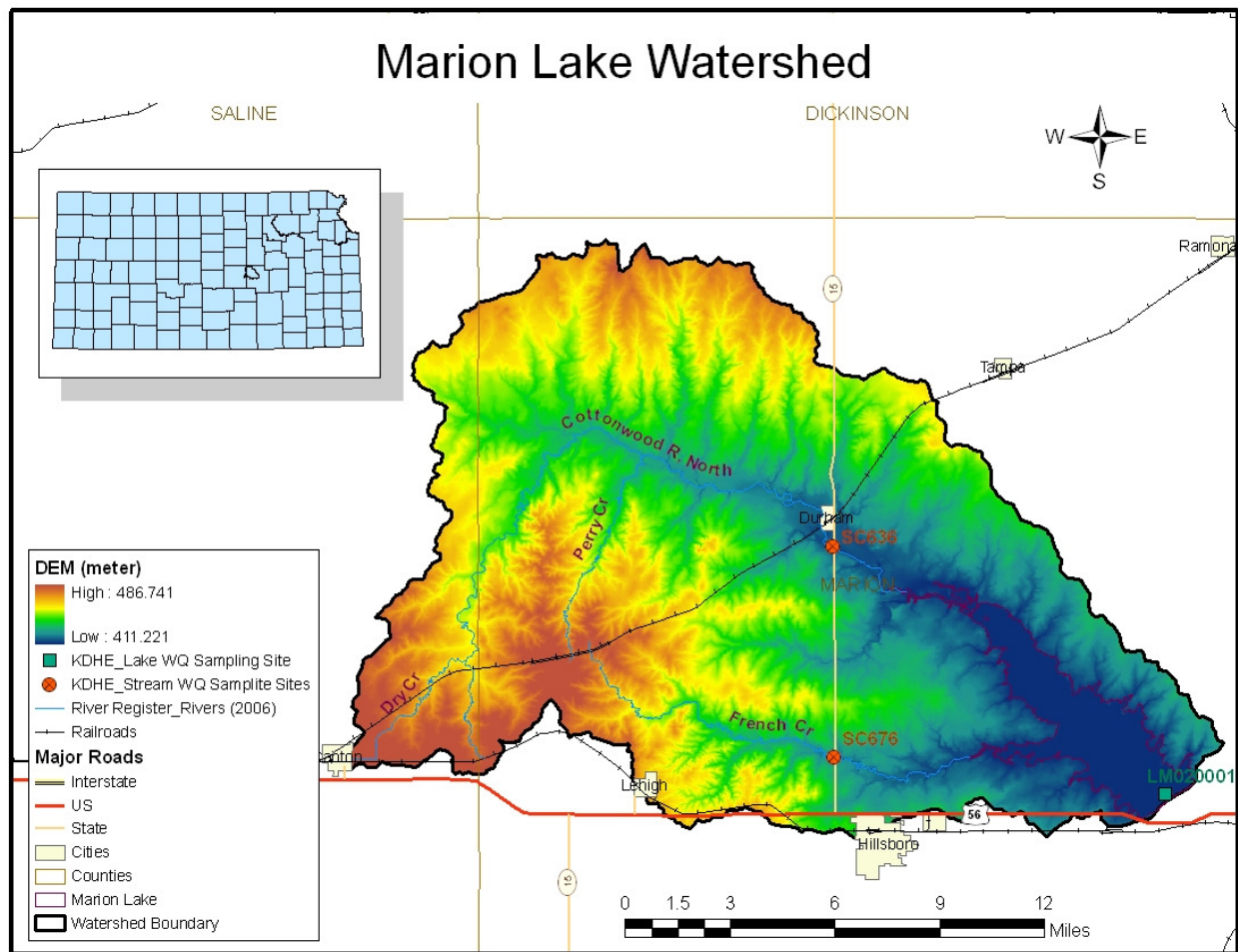


Figure 1. DEM and location of KDHE water quality sampling sites of Marion Lake Watershed.

2. CURRENT WATER QUALITY CONDITION AND DESIRED ENDPOINT

Level of Eutrophication: Trophic State Index = 59 (Fully Eutrophic), ranging from 36 in 1993 to 66 in 2002.

The Trophic State Index (TSI) is derived from the chlorophyll *a* concentration (Chla). Trophic state assessments of potential algal productivity were made based on Chla, nutrient levels, and values of the Carlson Trophic State Index (TSI). Generally, some degree of eutrophic conditions is seen with Chla over 12 µg/L and hypereutrophy occurs at levels over 30 µg/L. The Carlson TSI derives from the Chla concentrations and scales the trophic state as follows:

1. Oligotrophic TSI < 40
2. Mesotrophic TSI: 40 - 49.99
3. Slightly Eutrophic TSI: 50 - 54.99
4. Fully Eutrophic TSI: 55 - 59.99
5. Very Eutrophic TSI: 60 - 63.99
6. Hypereutrophic TSI: 64

Lake Monitoring Sites: Station LM020001 in Marion Lake; Seven surveys, 1987 – 2005; Tulsa District, U.S. Army Corps of Engineers, 2004 – 2006; Kansas Water Office/Kansas Biological Survey (KBS), 2006

Stream Chemistry Sites: Station 636 North Cottonwood River near Durham; 1993 – 2005
Station 676 French Creek near Hillsboro; 1993 – 2005

Long-Term Hydrologic Conditions: Total inflow and outflow measured at the dam of Marion Lake by Tulsa District of U.S. Army Corps of Engineers during the period from 1995 to 2006 is shown in **Figure 2**. Median total inflow for Marion Lake is 10 cfs (19.87 ac-ft) while 10% and 80% exceedance total inflow are 200 cfs (397.44 ac-ft) and 1 cfs (1.99 ac-ft), respectively. Median outflow for Marion Lake is 3 cfs (5.96 ac-ft) while 10% and 80% exceedance outflow are 53 cfs (105.32 ac-ft) and 2 cfs (3.97 ac-ft), respectively. During this period, annual average total inflow is 70,895 ac-ft, ranging from 20,756 ac-ft in 2006 to 159,890 ac-ft in 1998 while annual average outflow is 33,172 ac-ft, ranging from 1,699 ac-ft to 155,705 ac-ft (**Figure 3**). Annual rainfall measured at the watershed and dam is shown in **Figure 4**. Average rainfall is 28 in (0.73 cm). Generally, 1995 – 1999 are considered wet years while 2000 – 2006 are a dry period. Average rainfall in 1995 – 1999 is 35 in (89 cm) while average rainfall is 24 in (60 cm) 2000 – 2006.

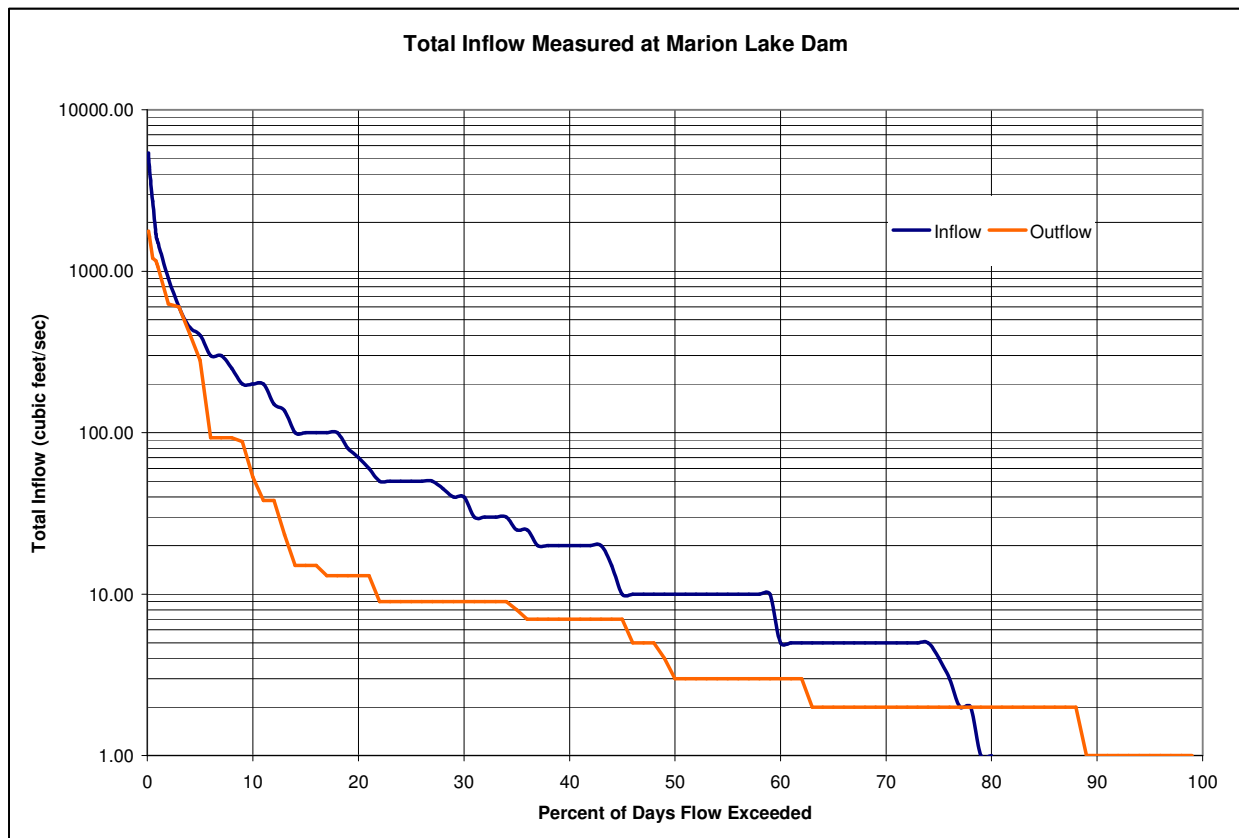


Figure 2. Flow duration plot of total Inflow and outflow at Marion Lake during 1995 – 2006.

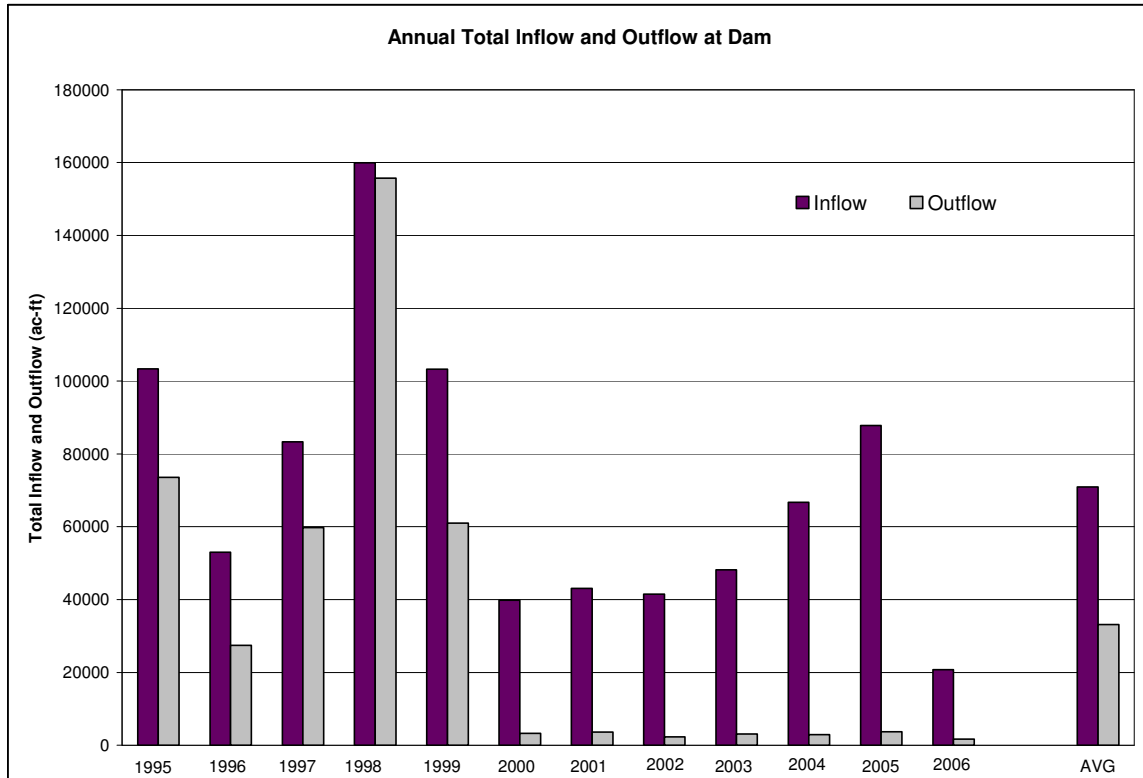


Figure 3. Annual total inflow and outflow measured at Marion Lake during 1995 – 2006.

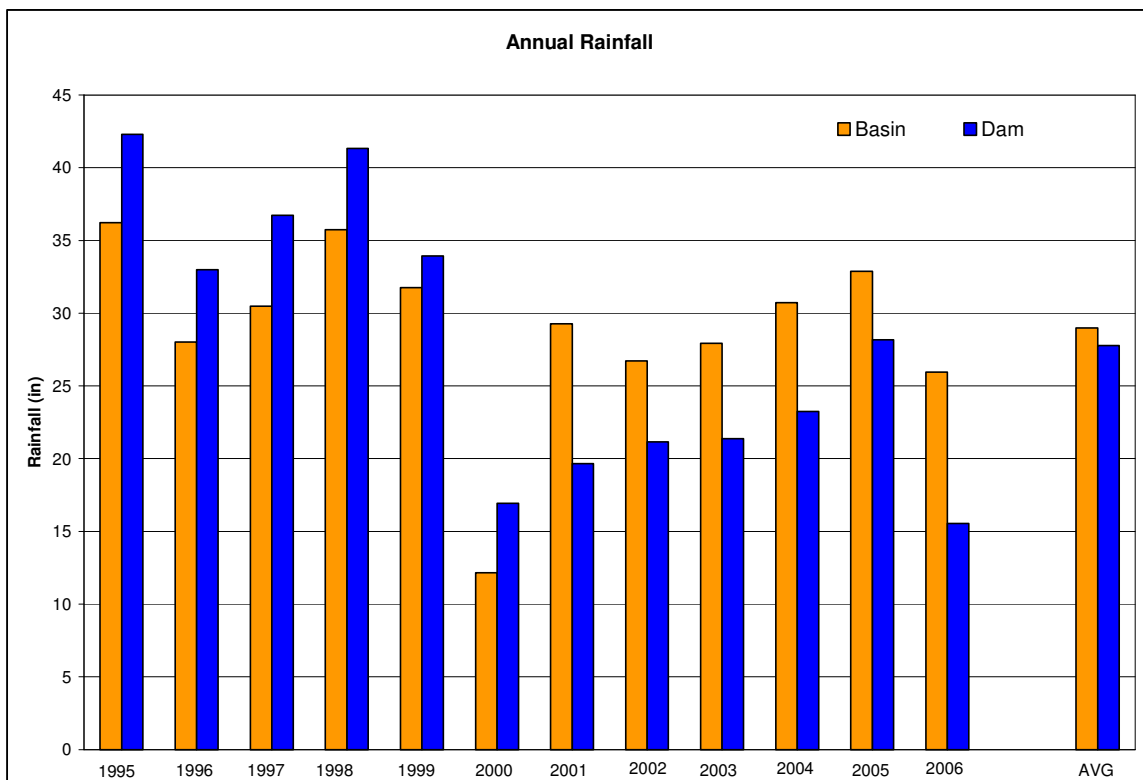


Figure 4. Rainfall measured at Marion Lake during 1995 – 2006.

Current Condition: Marion Lake frequently experiences cyanobacterial blooms in the recent years. In July 10 of 2003, total algal cell count [*Anabaena* sp. (121,647 cells/ml) and *Microcystis* sp. (33,765,339 cells/ml)] in drinking water intake far exceeded the World Health Organization's recommended guidelines of very high risk level (100,000 cells/ml). Marion Lake has Chla concentrations averaging 18.0 ppb during the growing season (May-September) of 1987–2006, with a corresponding Trophic State Index (TSI) value of 59. **Figure 5** shows the annual changes of Chla chlorophyll *a* concentrations in 1987–2006. As indicated, chlorophyll *a* concentrations gradually increase over time and their values have consistently appeared above the end point for Primary Contact Recreation Use (12 µg/L) since 2002.

Total phosphorus (TP) concentrations average 89 µg/L, ranging from 5 µg/L in 1987 to 180 µg/L in 2006, and show an increase pattern from 1987 to 2006 (**Figure 6**). However, total nitrogen (TN) concentrations display an opposite trend. Over these years, TN values range from 2.18 mg/L in 1993 to 0.97 mg/L in 2006, with an average of 1.25 mg/L. The ratio of total nitrogen (TN) and TP has been used to determine which of these nutrients is most likely limiting plant growth in Kansas aquatic ecosystems (Dzialowski et al., 2005). Generally, lakes that are N limited have water column TN:TP ratios < 8 (mass); lakes that are co-limited by N and P have water column TN:TP ratios between 9 and 21; and lakes that are P limited have water column TN:TP ratios > 29. For Marion Lake, TN:TP ratios, though averaging 14, shifted from 21 during 1993–1999 to 8 in 2002–2006, suggesting that algal population has been dominated by blue-green algae (cyanobacteria) in the recent years. A recent nutrient bioassay study conducted by the KBS confirmed that Marion Lake is a N-limited lake (Dzialowski et al., 2007).

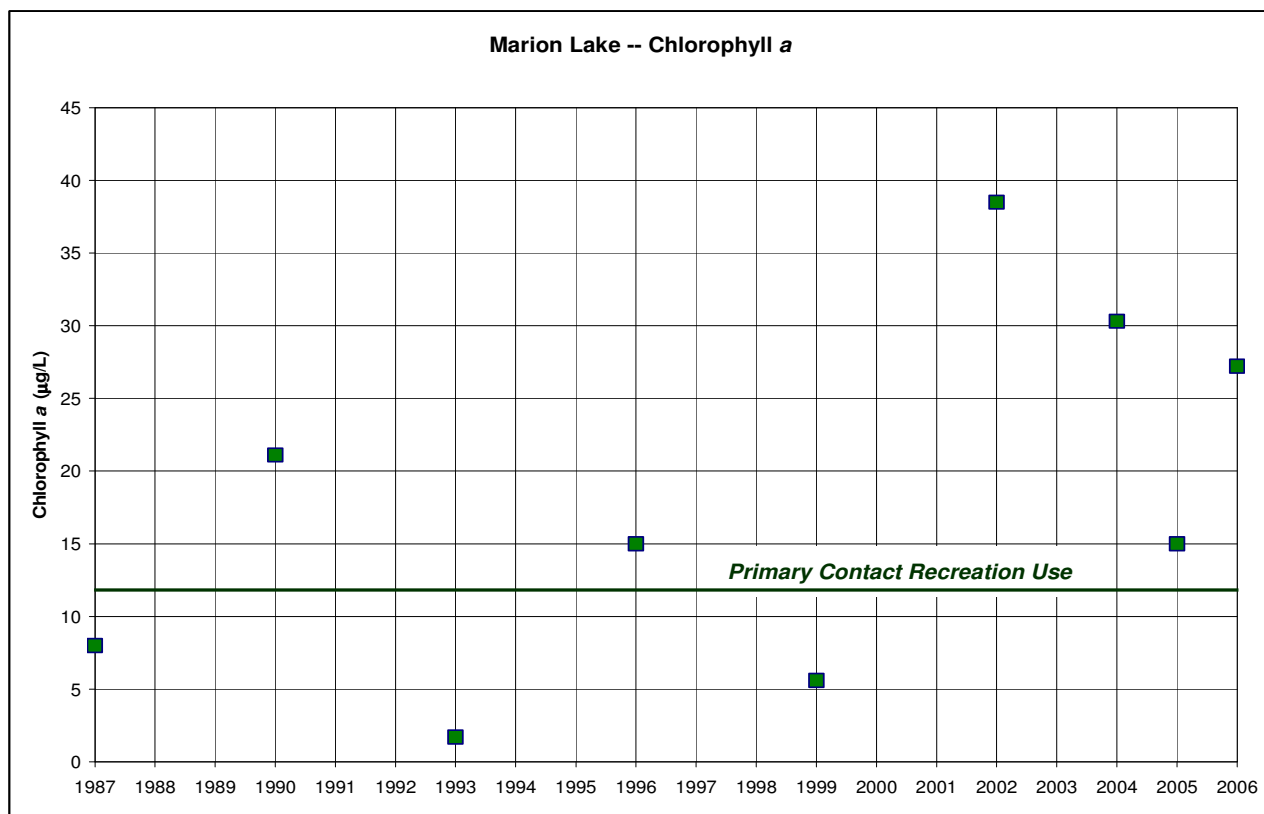


Figure 5. Chlorophyll *a* concentrations at Marion Lake Site during 1987 – 2006.

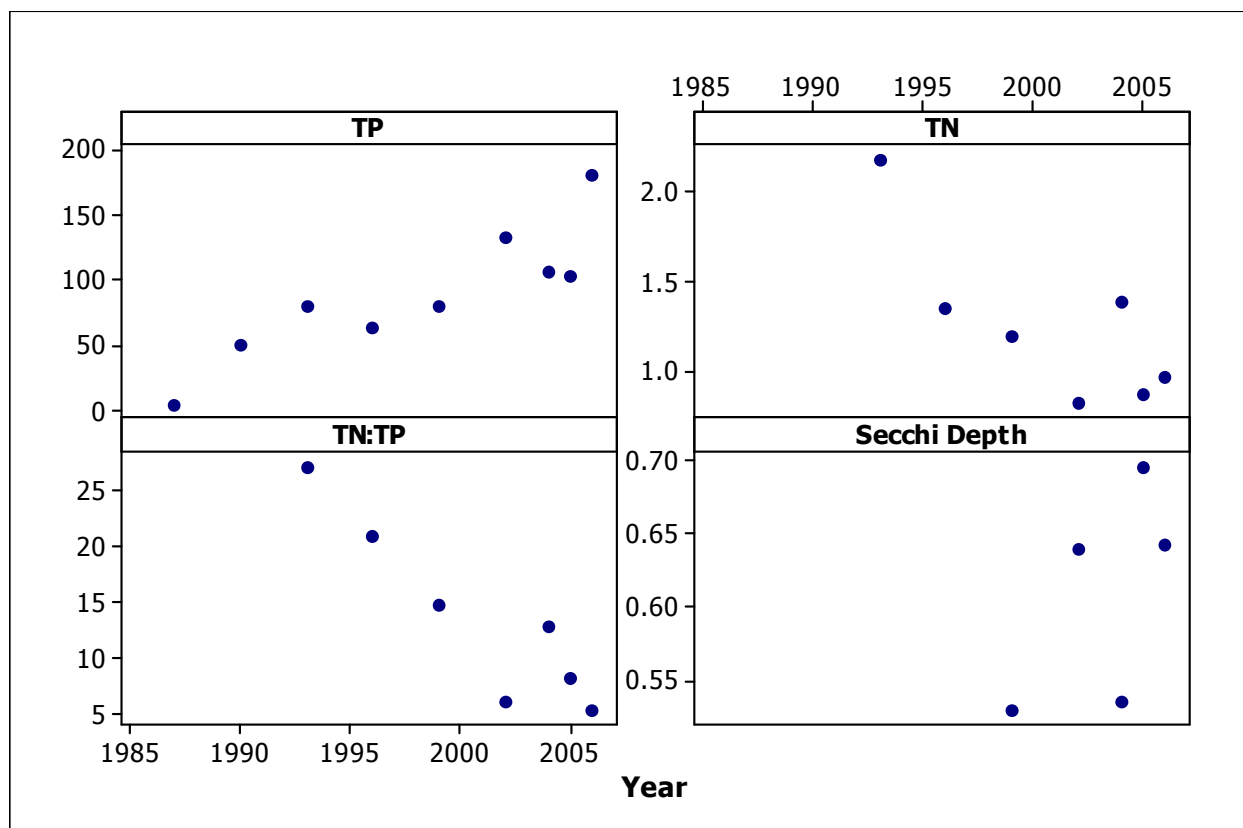


Figure 6. Scatter plots of TP, TN, TN:TP and Secchi depth at Marion Lake. Measurement unit for TP, TN and Secchi depth are $\mu\text{g/L}$, mg/L , and meter, respectively.

Figure 7 summarizes the current and possible future trophic conditions of Marion Lake using a multivariate TSI compassion chart. $\text{TSI}(\text{Chla}) - \text{TSI}(\text{TP})$ is plotted on the vertical axis. Points below $\text{TSI}(\text{Chla}) = \text{TSI}(\text{TP})$ indicate situations where phosphorus may not be limiting Chla whereas points above $\text{TSI}(\text{Chla}) = \text{TSI}(\text{TP})$ indicate the opposite. $\text{TSI}(\text{Chla}) - \text{TSI}(\text{SD})$ is plotted on the horizontal axis, showing that if the Secchi depth (or SD) is greater than expected from the Chla trophic index, large particles dominate, along with zooplankton grazing. If the Secchi depth is less than expected from the Chla index, transparency is dominated by non-algal factors such as color or inorganic turbidity. Points near or on the diagonal line occur in turbid situations where phosphorus is bound to clay particles and therefore turbidity values are closely associated with phosphorus concentrations (Dip-In, 2007).

The multivariate TSI plot indicates that Marion Lake has ample phosphorus levels and is N-limited. According to the most recent KDHE's lake survey, algal communities in Marion Lake, based on both cell count and biovolume, were dominated by blue-green algae (Carney, 2006). It has been known that the blooms of blue-green algae are a major issue for Marion Lake, and the intense episodic algal blooms have forced beach closing and prompted public water supplies to use alternative water sources for local communities in 2003.

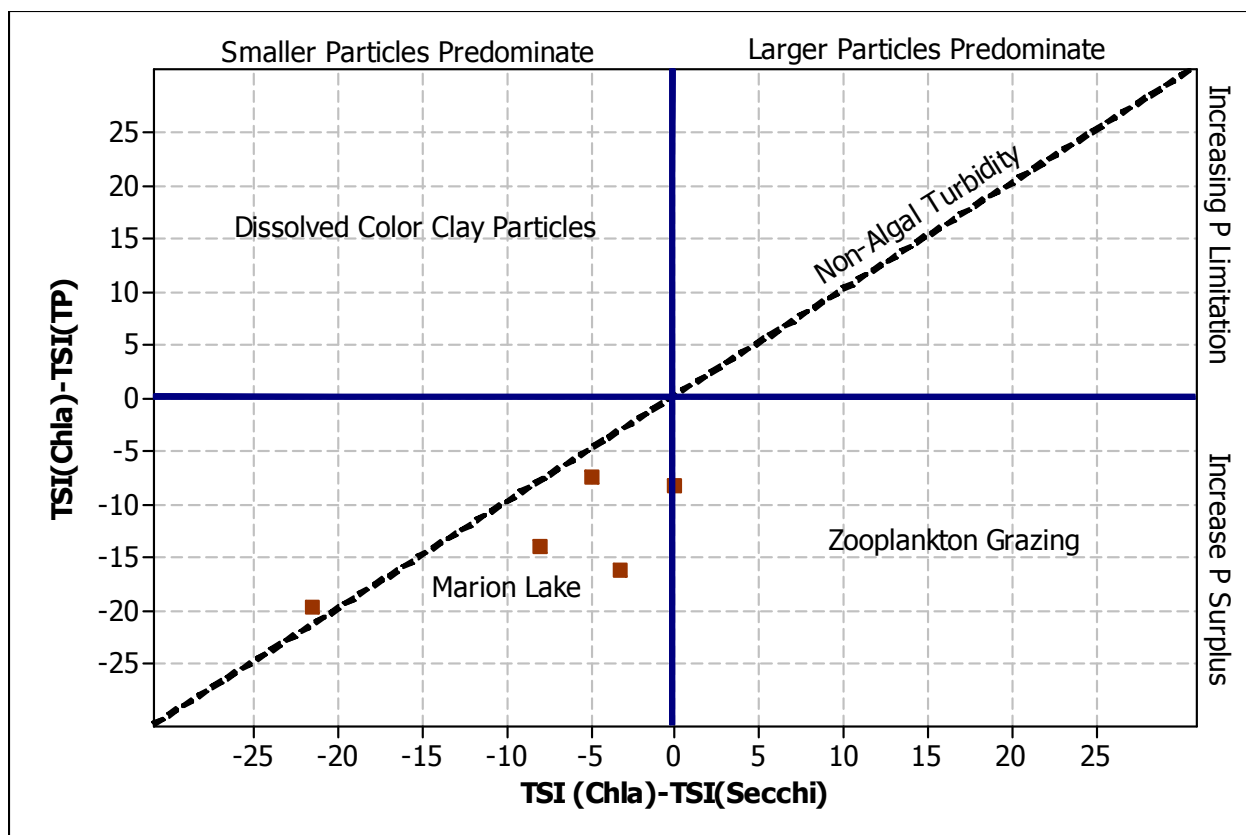


Figure 7. Multivariate TSI compassion chart of Marion Lake.

Changes in Chla levels are closely associated with hydrologic conditions and nutrient flux from the watershed as well as internal nutrient cycling and regeneration from the lake bottom. **Figure 8** shows common water quality patterns observed in Marion Lake. In general, negative relationships are found between Chla and TN and TN:TP while positive relationships are found between Chla and TP. Marion Lake tends to have high Chla concentrations when TN:TP ratios are low. Low TN:TP ratios tend to appear under high lake clarity (low Secchi depth) conditions. Low Chla levels typically occur when the total inflow of the lake is high (**Figure 9**), revealing that hydrologic regime plays an important role in regulating Chla level.

Table 1 shows the water quality conditions over years. Non-Algal Turbidity (NAT) is an index used often to determine light limitation in a lake. Generally, lakes that are light limited have NAT value $>1 \text{ m}^{-1}$; lakes that are somewhat limited by light have NAT values between 0.4 m^{-1} and 1 m^{-1} ; and lakes that are not light limited have NAT values $< 0.4 \text{ m}^{-1}$. For Marion Lake, NAT values average 1.08 m^{-1} , suggesting that inorganic turbidity plays an important limiting role on algal communities.

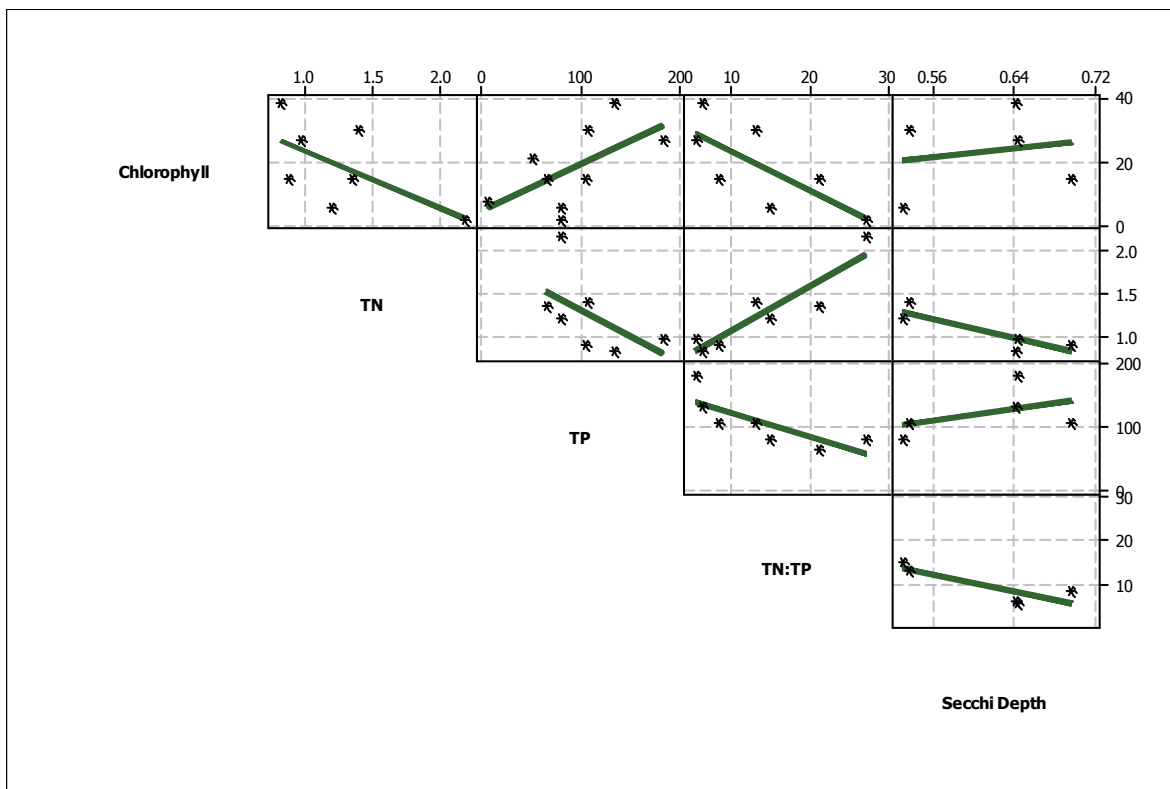


Figure 8. Common water quality patterns in Marion Lake during 1987 – 2006.

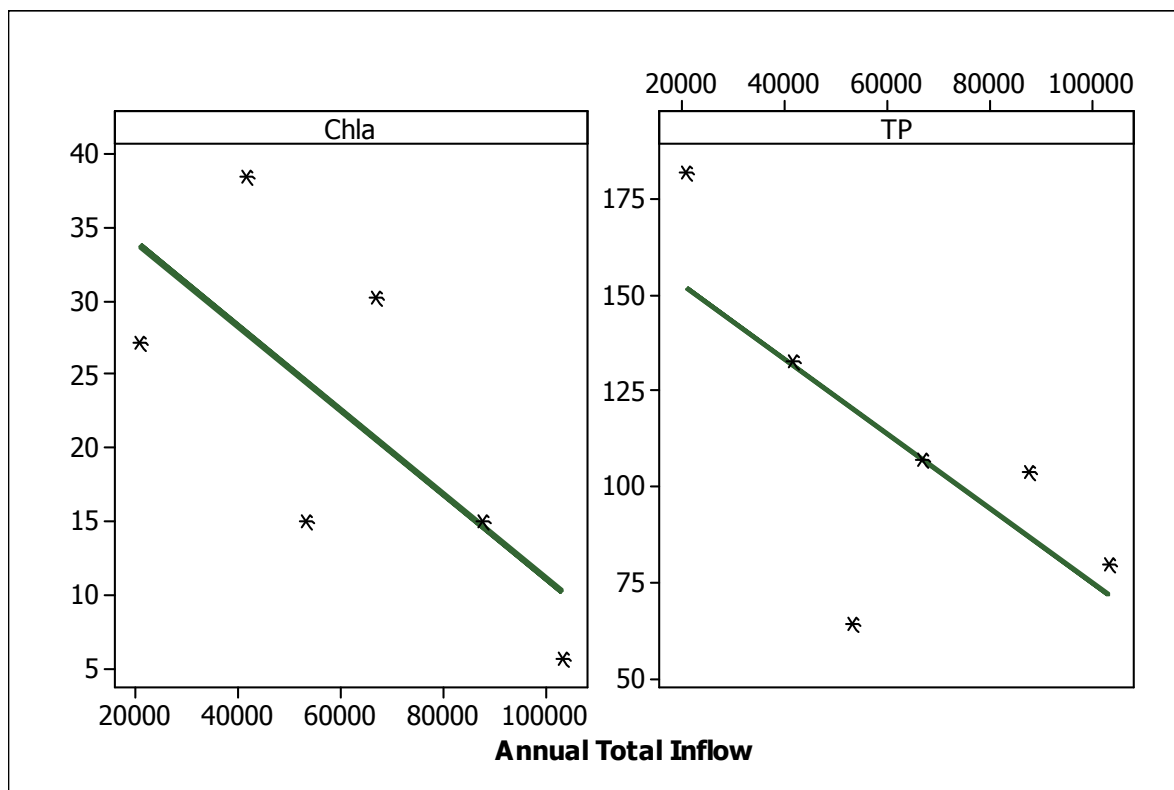


Figure 9. Scatter plots of Chla and TP vs annual total inflow.

Table 1. Water quality conditions measured in 1987 – 2006.

Year	Chla ($\mu\text{g L}^{-1}$)	TN (mg L^{-1})	TP ($\mu\text{g L}^{-1}$)	TN/TP	Turbidity (NTU)	TSS ($\mu\text{g L}^{-1}$)	Secchi (m)	NAT (m^{-1})
1987	8		0.01		11.0	13.0		
1990	21		0.05		7.8			
1993	2	2.18	0.08	27	4.0	6.0		
1996	15	1.35	0.06	21	8.0	15.0		
1999	6	1.19	0.08	15	8.2	9.0	0.53	1.75
2002	39	0.82	0.13	6	9.9	17.0	0.64	0.60
2004	30	1.39	0.11	13	20.7	12.7	0.54	1.11
2005	15	0.87	0.10	8	15.7	13.2	0.70	1.06
2006	27	0.97	0.18	5	25.1	14.2	0.64	0.87

As indicated in **Figure 9**, the negative relationship between TP and annual total inflow shows that the release of internal phosphorus from the sediment is another nutrient source of triggering high Chla levels in the lake. A recent study of internal nutrient regeneration conducted by the KBS revealed that internal phosphorus-releasing rates averaged 23 mg/m²/day under anoxic conditions in the main basin (or lacustrine) area and 21 mg/m²/day for the whole lake (Dzialowski et al., 2007). If Marion Lake undergoes DO stratification for one month, for example, the P load released from the sediment would account for about 8% of the watershed TP load for the main basin area and 26% of the watershed TP load for the entire lake. **Table 2** summarizes median trophic conditions of Marion Lake in relation to other federal lakes in the state. As indicated, Marion Lake's trophic values are higher than those of the federal lakes and over reference lake trophic benchmarks suggested for Kansas (Dodds et al., 2006).

Table 2. Median trophic indicator values of Marion Lake in comparison with other federal lakes and draft lake nutrient benchmarks in Kansas. The nutrient benchmarks were derived from 47-58 lakes and reservoirs, based on the data collected between 1985 and 2002.

Trophic Indicator	Marion Lake	Federal Lakes	Central Great Plains	Flint Hills	Statewide Benchmark
Secchi depth (cm)	64	95	117	149	129
TN ($\mu\text{g/L}$)	1,190	903	695	301	625
TP ($\mu\text{g/L}$)	80	76	44	19	23
Chlorophyll <i>a</i> ($\mu\text{g/L}$)	15	12	11	5	8

Desired Endpoint for Marion Lake 2011 – 2016:

To improve the trophic condition of the lake from its current very eutrophic status to slightly eutrophic, based on 1996 – 2005 watershed/lake modeling results, the interim endpoint will be to maintain the growing-season's Chla concentration below 12 $\mu\text{g/L}$ by 2014. The final desired endpoint will be to reduce the growing-season's Chla concentration below 10 $\mu\text{g/L}$ by 2016 for a water supply lake. The endpoint water quality (Load Capacity) for Marion Lake is summarized in **Table 3**.

Table 3. Desired water quality endpoints for Marion Lake over 2011 – 2016.

Parameter	Current Condition	Interim TMDL	Final TMDL
TN Load (lbs/yr)	621,825	173,742	115,824
TP Load (lbs/yr)	148,698	44,438	29,619
TN Concentration (µg/L)	1123	663	550
TP Concentration (µg/L)	98	59	48
Chlorophyll <i>a</i> (µg/L)	21	<12	<10

3. SOURCE INVENTORY AND ASSESSMENT

NPDES: Four NPDES permitted facilities are located within the watershed (**Figure 10**). Two are non-overflowing lagoon systems (**Table 4**). Non-overflowing lagoons are prohibited from discharging and would only contribute a total phosphorus or ammonia load under extreme precipitation events (flow durations exceeded up to 5 percent of the time). Such events would not occur at a frequency or for a duration sufficient to add to the impairments in Marion Lake.

Canton and Lehigh MWTP facilities discharge their effluents via Dry Creek and French Creek, respectively, and eventually these treated sewages flow into Marion Lake. For lagoon systems in Kansas, average effluent TN and TP concentrations are 7 mg/L and 2 mg/L, respectively (written communication, Mike Tate, BOW, KDHE).

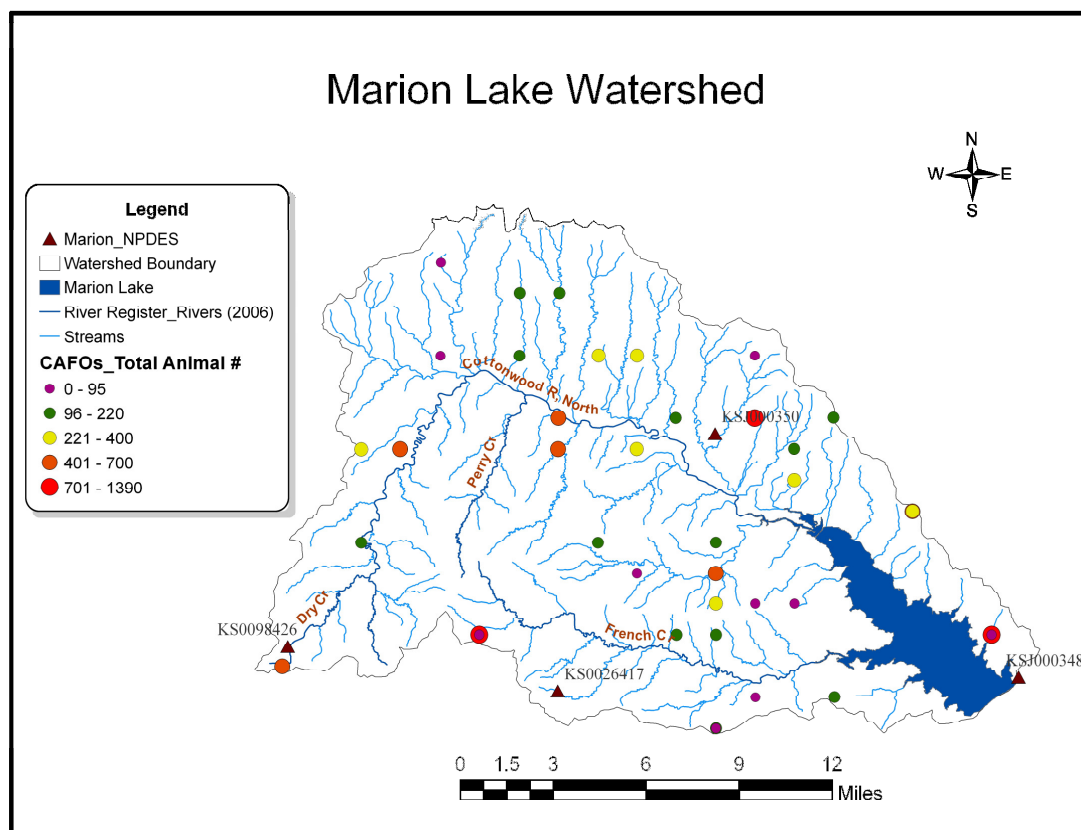


Figure 10. Location of NPDES and CAFO sites in the Marion Lake Watershed.

Table 4. Characteristics of NPDES facilities located in the Marion Lake Watershed.

NPDES Permit	Facility Name	Type	Design Flow	Reach (Segment)	Permit Expired
KS-0098426	Canton MWTP	Three-Cell Lagoon	0.12 MGD	Dry Creek (40)	12-31-2008
KSJ-000350	Durham MWTP	Four-Cell Lagoon	Non-Overflowing	-	4-30-2009
KS-0026417	Lehigh MWTP	Three-Cell Lagoon	0.03 MGD	French Creek (16)	5-31-2008
KSJ-000348	Marion Co. S.D. #1	Two-Cell Lagoon	Non-Overflowing	-	1-31-2009

Land Use: The predominant land use in the Marion Lake Watershed is cultivated cropland (43%) and grassland (40%), according to 2001 National Land Cover Data. Together, they account for 83% of the total land area in the watershed. Approximately 3% of the land is occupied by deciduous forest, whereas 2% is pasture/hay. Urban area, such as residential, commercial and industrial uses, comprises only less than 1% of the watershed (**Figure 11**).

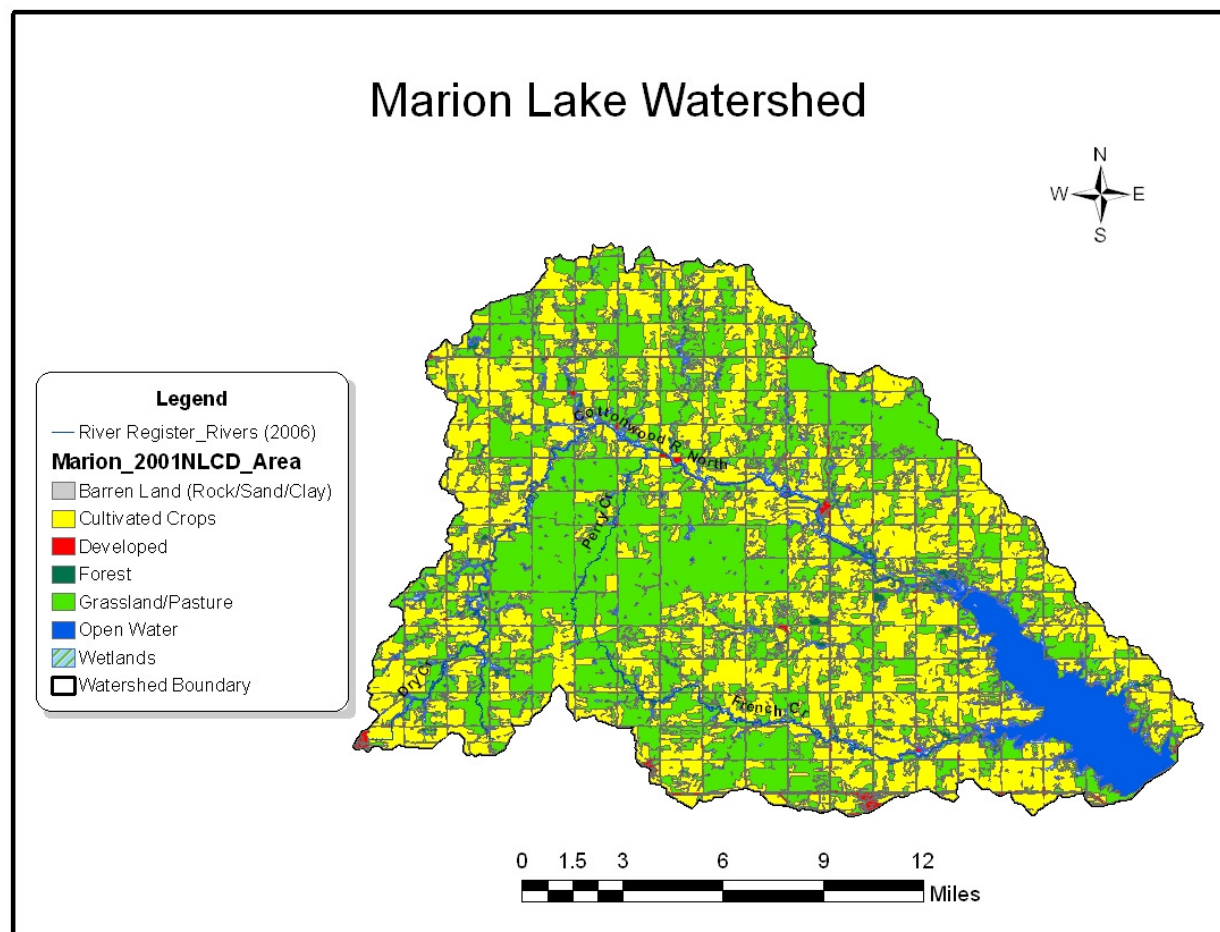


Figure 11. Land use and land cover map (2001 NLCD) of the Marion Lake Watershed.

Livestock Waste Management Systems: There are 38 confined animal feedlot operations (AFO/CAFOs) registered (either certified or permitted), which are primarily located in the central portion of the watershed (**Figure 10**). All of these permitted livestock facilities (10 dairy, 21 beef, 4 swine, and 3 mixed of beef/horse/swine) have waste management systems designed to minimize runoff entering their operation or detaining runoff emanating from their facilities. In addition, they are designed to retain a 25-year, 24-hr rainfall/runoff event as well as an anticipated two weeks of normal wastewater from their operations. Typically, this rainfall event coincides with streamflow that is less than 1-5% of time. Though the total potential number of animals is 11,755 head in the watershed, the actual number of animals at the feedlot operations is typically less than the allowable permitted number.

Approximately 40% of land around the lake is grassland, and the grazing density of livestock is moderate in summer and high in winter. According to the National Agricultural Statistics Service, number of cattle surveyed for Marion and the surrounding counties are shown in **Figure 12**. In average, there are 73,288 head of cattle, ranging from 62,900 in 2005 to 81,400 in 1999.

Because of seasonally high density of these livestock operations in the watershed, the animal waste from both confined and unconfined feeding sites is considered a major potential source of phosphorus loading going into Marion Lake. The laboratory results (Mehlich 3) of 319 soil samples collected from Marion County show that available P averages 36 mg/L in the top 6" soils, with a range from 2.5 mg/L to 51+ mg/L (written comm., David Mengel, KSU, 2007).

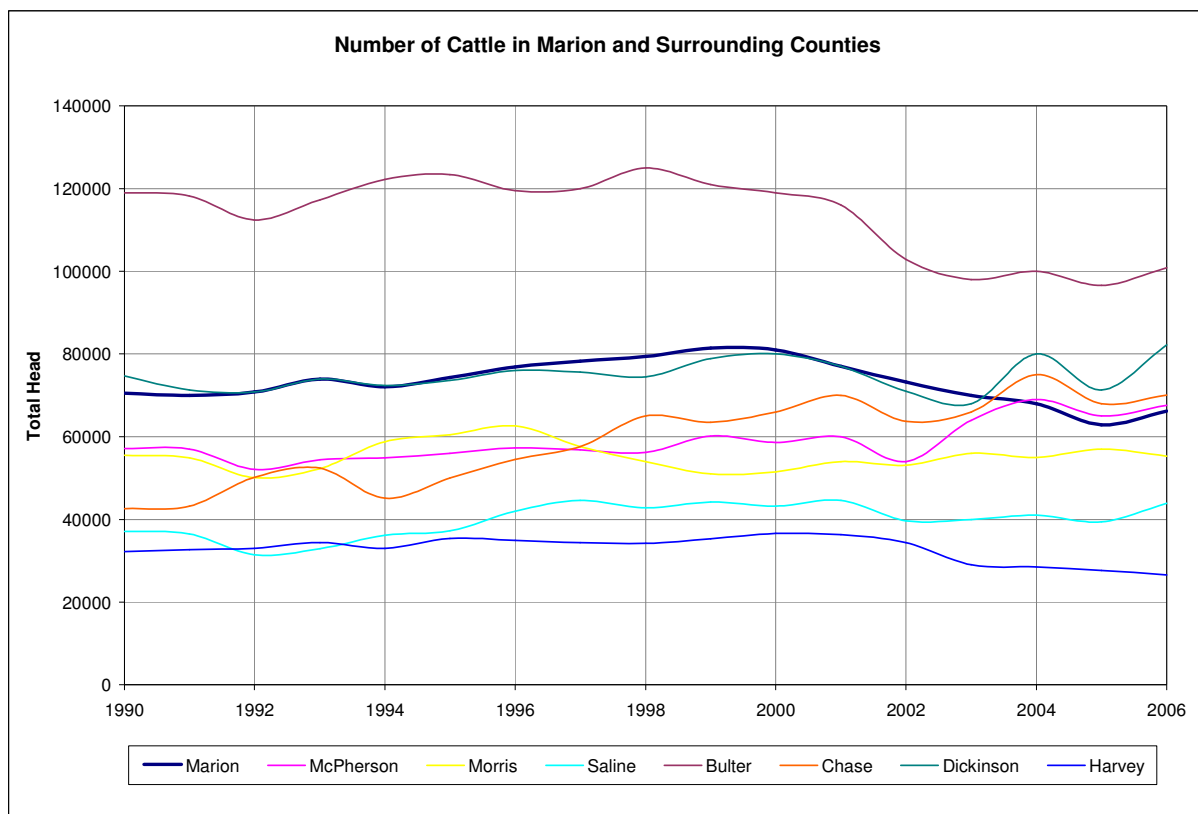


Figure 12. Cattle distribution in the grassland of Marion County and surrounding counties.

On-Site Waste Systems: The population density of the watershed is 10.5 people per square mile. The population changes are shown in **Table 5** for the four cities within the watershed. Many septic systems are scattered around the lake. Though Marion County has approximately 1,663 septic systems, the failing rate of these systems is 0.93% (National Environmental Service Center, 1998). The failing septic systems are seen as a minor source of nutrients to the lake.

Table 5. Expected population change for the cities of Canton, Durham, Hillsboro and Lehigh from 2000 – 2020.

City	Changes (%)
Canton	16.7
Durham	-11.4
Hillsboro	27.2
Lehigh	5.1

Contributing Runoff: **Figure 13** shows soil permeability values across the watershed, based on NRCS STATSGO database. The watershed-wide soil permeability averages 0.62"/hr. According to an USGS open-file report (Juracek, 2000), the threshold soil-permeability values that represent very high, high, moderate, low, very low, and extremely low rainfall intensity, were set at 3.43, 2.86, 2.29, 1.71, 1.14, and 0.57"/hr, respectively. The lower rainfall intensities generally occur more frequently than the higher rainfall intensities. The higher soil-permeability thresholds imply a more intense storm during which areas with higher soil permeability potentially may contribute runoff. Runoff is chiefly generated as infiltration excess with rainfall intensities greater than soil permeabilities. As soil profiles become saturated, excess overland flow is produced.

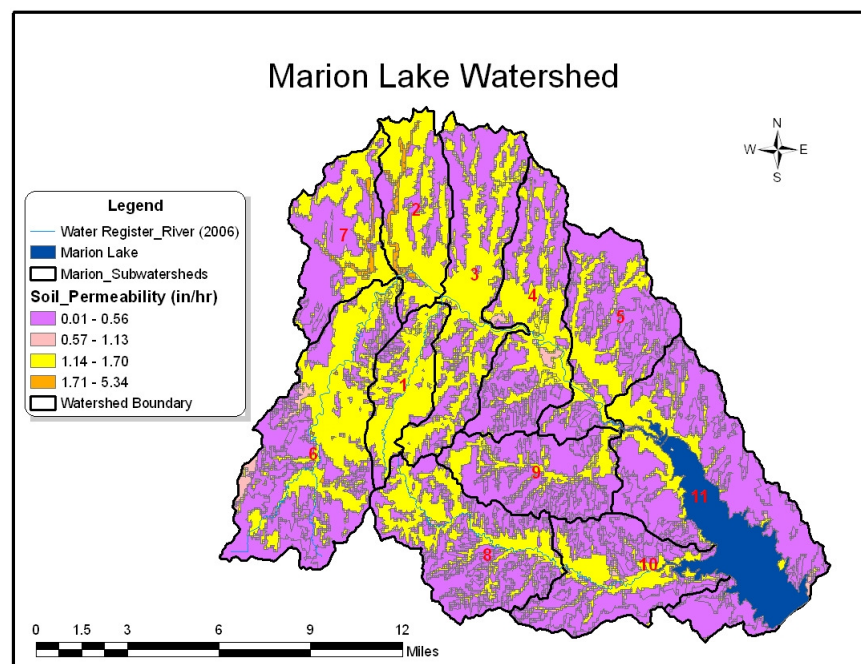


Figure 13. Soil permeability of Marion Lake Watershed.

For the Marion Lake Watershed, about 99% of the total area has soil permeability value either less than or equal to 1.71"/hr. Under the very low (1.14"/hr) runoff condition, the potential contributing area is about 64%. Storms that produce 0.57"/hr of rain will generate runoff from 59% of the watershed area, which is dominated by cultivated cropland.

Background Levels: Approximately 3% of land in the watershed is forest. Nutrients released from leaf decomposition may be contributing to the nutrient loading. The atmospheric nutrients and geological formations (i.e., soil and bedrock) may also contribute to the nutrient load. As indicated in the previous section, the average internal phosphorus-releasing rate is 21 mg/m²/day under anoxic conditions in the lake, and thus the sediment nutrient regeneration and cycling may be an important nutrient source as a result of the interplay between the mixing and thermo/DO stratification in the lake. According to the National Atmospheric Deposition Program/National Trend Network, the annual N load via wet deposition is 730 mg/m².

4. ALLOCATION OF POLLUTANT REDUCTION RESPONSIBILITY

The watershed and lake models used for this TMDL analysis were Generalized Watershed Loading Function (GWLF) and BATHTUB, respectively. GWLF is a mid-range watershed model that provides both agricultural and urban daily runoff, sediment, and nutrient simulations (Haith et al., 1992; USEPA, 1999), and has been widely used in many states including PA, IL, OH, ME, and VA. BATHTUB is an empirical receiving water quality model, that was developed by U.S. Army Corps of Engineers (Walker, 1996), and has been commonly applied in the nation to address many TMDLs relating to issues associated with morphometrically complex lakes and reservoirs (Mankin et al., 2003; Wang et al., 2005).

The Marion Lake Watershed was divided into 11 small subwatersheds (**Figure 14**). The French Creek Watershed, with Site SC676, was used to calibrate the GWLF model. The Durham Watershed along the North Cottonwood River, with Site SC636, was used for model validation. **Table 6** shows the mean concentrations of TSS and nutrients at these rotational sampling sites. Streamflow of the French Creek and Durham Watersheds were calculated, based on their proportional watershed size to the whole watershed, using the total inflow values. A stream recession coefficient for the French Creek Watershed was derived from a nearby USGS gaging station (07180500) using Web-based Hydrograph Analysis Tool (Purdue University, 2007). To capture a wide range of hydrologic conditions, the GWLF model was run for a 10-year period from 1996 to 2005, marked by a wet period following by a pervasive dry period.

Table 6. Mean (\pm Standard Deviation) for TSS, TN, and TP in 1993 – 2005.

Sampling Site	TSS (mg/L)	TN (mg/L)	TP (mg/L)
SC636 (Durham)	66.44 (68.54)	1.35 (1.28)	0.19 (0.11)
SC676 (French)	52.87 (53.81)	1.36 (1.31)	0.20 (0.18)

Hydrologic simulation results for French Creek Watershed (calibration) and Durham Watershed (validation) are shown in **Figures 15** and **16**, respectively, and statistical measures are

summarized in **Table 7**. The results of error analysis indicate that the difference between the observed and simulated values were within 10%. Nash-Sutcliffe (NSF) index value, widely used for assessing the goodness of fit of hydrologic models, also shows that the results of model calibration and validation were within the recommended quantitative criteria of good and very good rating (Moriassi et al., 2007).

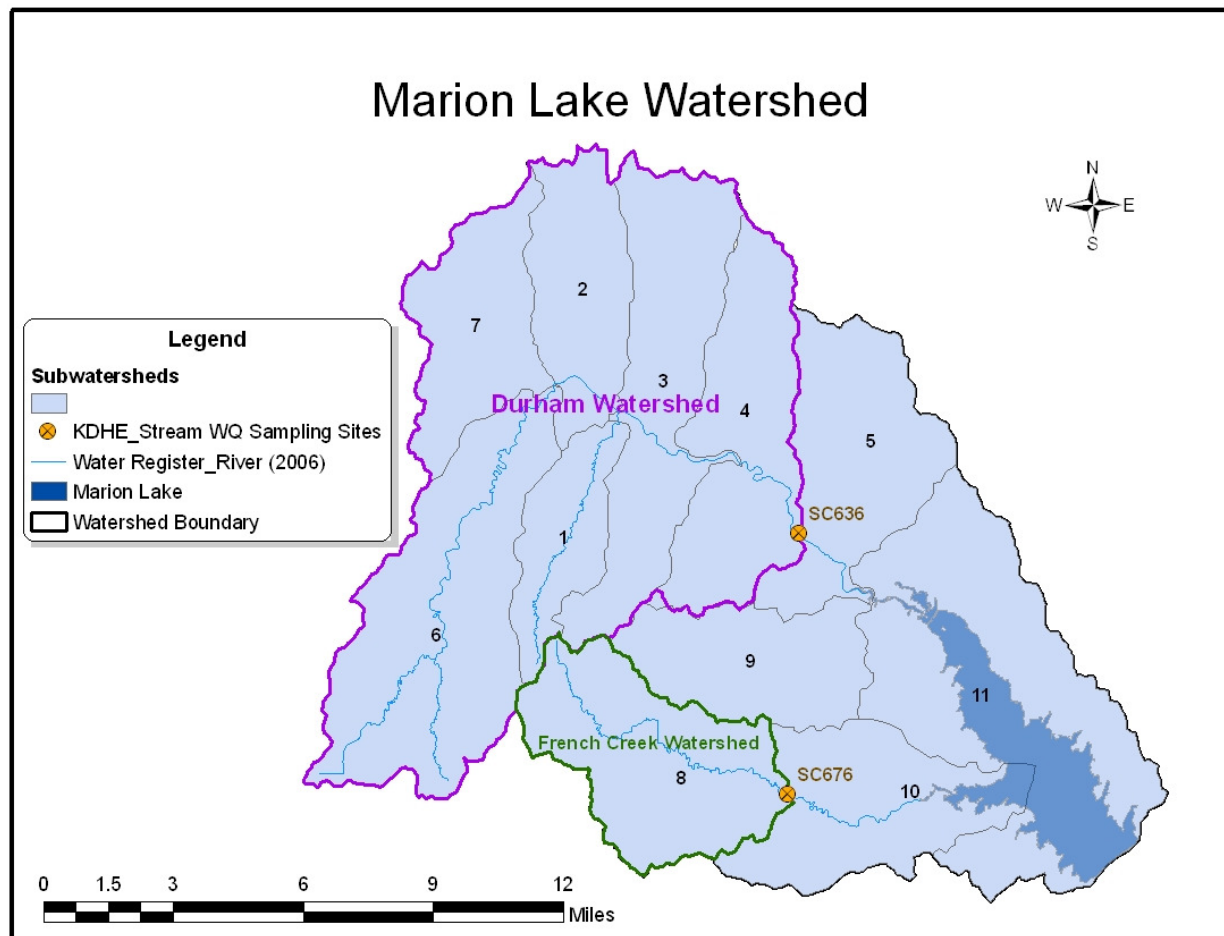


Figure 14. Subwatersheds used in GWLF modeling.

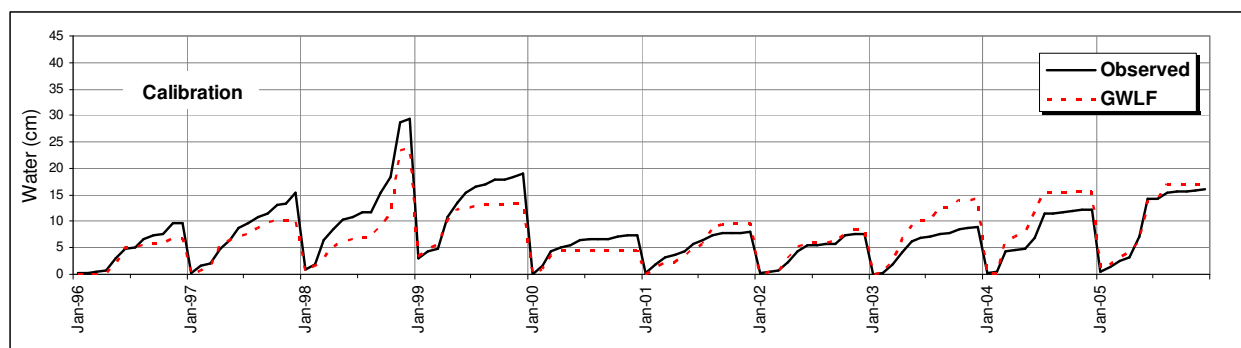


Figure 15. Cumulative plots of observed and simulated water flow for French Creek Watershed.

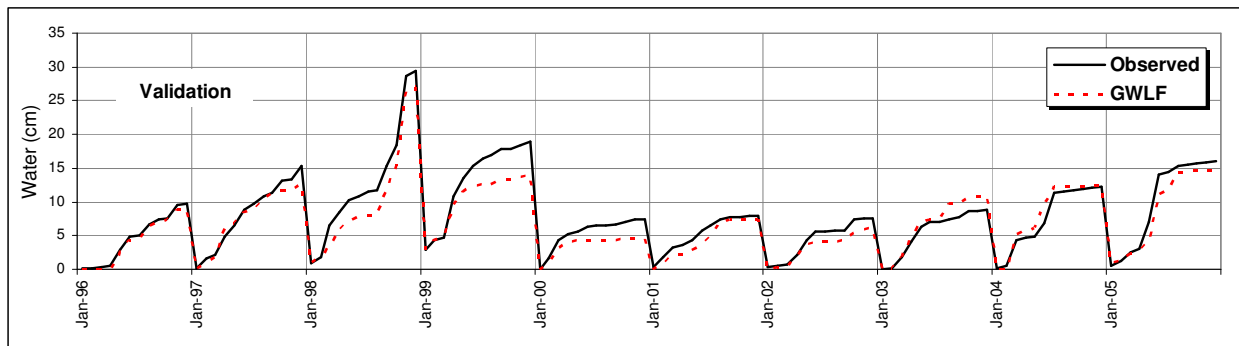


Figure 16. Cumulative plots of observed and simulated water flow for the Durham Watershed.

Table 7. Model performance for hydrologic measure from 1996 – 2005.

Watershed	Annual Mean (cm)		R-Squared (Monthly)	Nash-Sutcliffe (NSF)	
	Observed	GWLf		(Monthly)	(Annual)
French Creek	13.52	12.39	0.76	0.71	0.65
Durham	13.36	12.02	0.82	0.80	0.88
Marion, Total	13.62	12.33	0.80	0.77	0.89

The stream sampling locations (SC636 and SC676) are rotational monitoring sites where water samples are sampled bimonthly every four years. Because of the limited runoff data collected from these two sites, nutrient calibration and validation were based only on the French Creek Watershed (**Figure 17**). For this TMDL, nutrient loading from streambank erosion was estimated using a GIS technique developed by the Penn State Institutes of the Environment, Pennsylvania State University (Evans, et al., 2003). Watershed variables used in the technique included developed areas, animal density, runoff curve number (RCN), and landscape slope as well as soil erodibility. Runoff curve number were derived soil and land use data using a RCN calculator (Zhan and Huang, 2004) while slope length (LS) was generated from Annualized Nonpoint Source Pollution model (AnnAGNPS). The soil erodibility and cover management factors were obtained from the Natural resources conservation service. Nutrient buildup-washoff rates for urban areas were from the GWLF manual. Groundwater nutrient concentrations were based on the nutrient concentrations during the baseflow conditions. During the period of 1996 – 2005, the predicted annual loading averages of TN, dissolved N and TP for the French Creek Watershed were 14.73 metric tons (observed 15.07 metric tons), 5.71 metric tons (7.27 metric tons), and 3.21 metric tons (2.99 metric tons) respectively. The annual average streambank erosion contributed about 2% of the TN and 4% of TP loads from the watershed. **Table 8** summarizes statistical measures of model performance. Detailed GWLF input and setting information are shown in **Appendix A**.

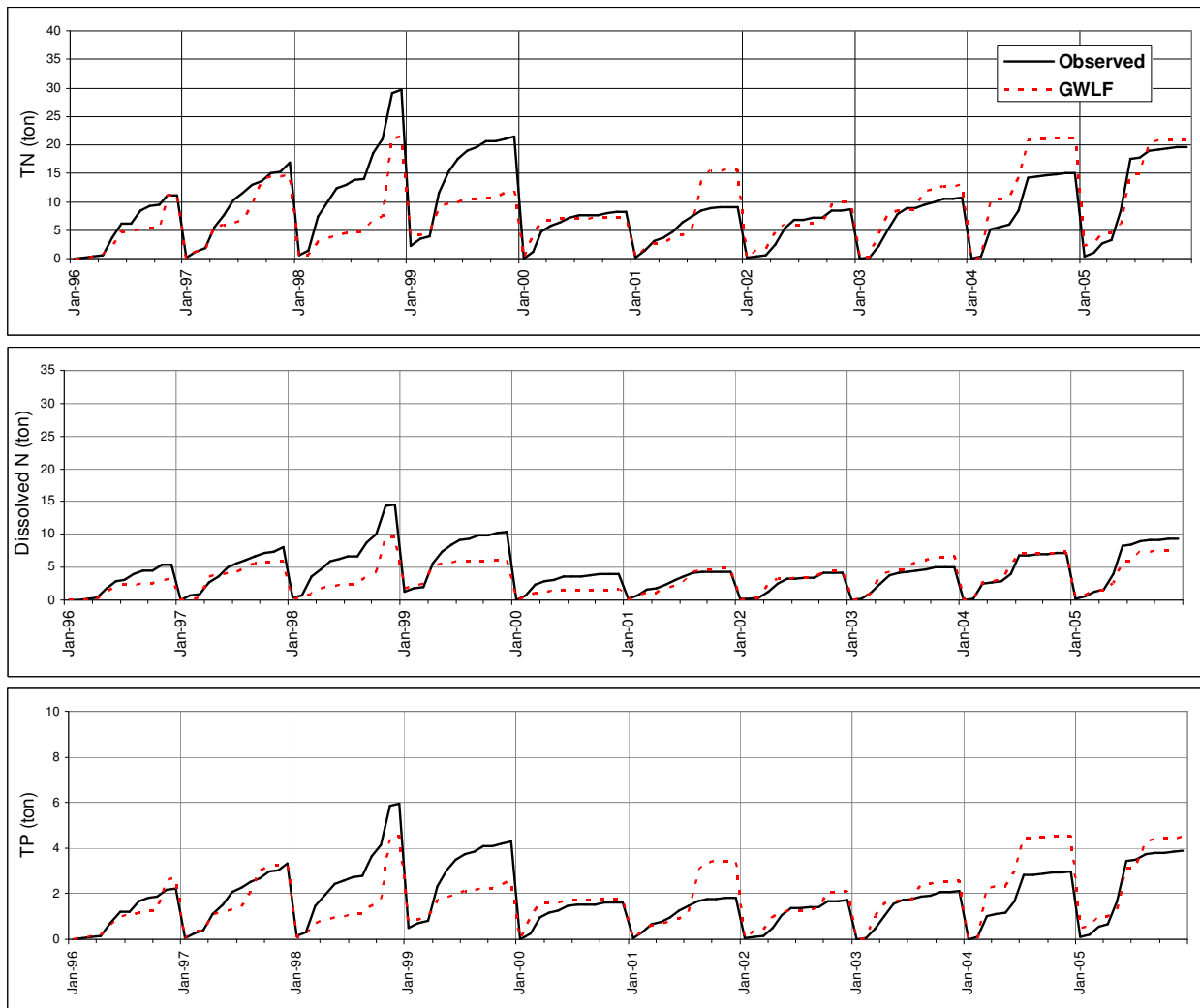


Figure 17. Cumulative plots of observed and simulated nutrients for the French Creek Watershed during 1996 – 2005.

Table 8. Summary of GWLF nutrient calibration and validation.

French Creek Watershed	TN (ton)		Dissolved N (ton)		TP (ton)	
	R-Squared	Error	R-Squared	Error	R-Squared	Error
1996-2000 Calibration	0.46	-0.24	0.64	-0.38	0.45	-0.15
2001-2005 Validation	0.53	0.28	0.65	0.01	0.51	0.38

Error = (Predicted annual average-Observed annual average)/Observed annual average.

The results of the 10-year model simulation (1996 – 2005) indicated that annual total watershed TN load to Marion Lake was 263.26 metric tons (579,172 lbs) while annual TP load was 67.33 metric tons (148,126 lb). Of which, streambank erosion only contributed 2.44 metric tons (5,372 lbs) and 0.95 metric tons (2,084 lbs) of TN and TP, respectively. Dissolved N load to the lake was 153.12 metric tons (336,864 lbs) per year, which accounted for about 60% of the TN from the watershed (**Table 9**). Cropland was the major nutrient source that contributed approximately 80% of the TN and 92% of the TP to the lake. Grassland, although occupying 42% of the watershed, contributed only about 13% of the TN and 6% of the TP to Marion Lake. **Table 10** lists the ranking of the per-unit-area nutrient loads for the 11 subwatersheds on an annual basis. The two MWTP facilities (Canton and Lehigh) together contributed 1.45 metric tons (3,183 lbs) of TN and 0.41 metric tons (909 lbs) of TP annually to Marion Lake. According to GWLF modeling results, the top five subwatersheds that exported more N loading were Basins 9, 10, 1, 4, and 11 whereas Basins 9, 10, 8, 4, and 1 were the subwatersheds contributing more TP loading. Unit nutrient loading maps are shown in **Appendix B**.

Table 9. GWLF-simulated watershed and subwatershed nutrient loads on an annual basis.

Subwatershed	Area (ac)	TN (ton)	Dissolved N (ton)	TP (ton)
Basin 1 (Perry Cr)	8502	18.76	12.11	4.61
Basin 2 (Middle N Cottonwood R)	8006	14.36	7.51	3.85
Basin 3 (Middle N. Cottonwood R)	13642	27.08	14.93	6.98
Basin 4 (Middle N. Cottonwood R)	11988	26.33	14.70	6.79
Basin 5 (Lower N. Cottonwood R)	11461	24.11	14.82	5.87
Basin 6 (Dry Creek)	18548	34.32	21.51	8.53
Basin 7 (Upper N. Cottonwood R)	5434	7.11	4.02	1.74
Basin 8 (Upper French Cr)	12617	27.20	14.16	7.39
Basin 9 (Silver Cr)	8620	23.93	11.81	6.51
Basin 10 (Lower French Cr)	9888	22.80	13.26	5.96
Basin 11 (Near lake area)	17032	37.31	24.40	9.10
<i>Total</i>		263.26	153.12	67.33

Table 10. Watershed ranking of annual TN and TP loads per unit of area.

Ranking	TN (lbs/ac)	Ranking	TP (lbs/ac)
Basin 9 (Silver Cr)	6.11	Basin 9 (Silver Cr)	1.66
Basin 10 (Lower French Cr)	5.07	Basin 10 (Lower French Cr)	1.33
Basin 1 (Perry Cr)	4.85	Basin 8 (Upper French Cr)	1.29
Basin 4 (Middle N. Cottonwood R)	4.83	Basin 4 (Middle N. Cottonwood R)	1.25
Basin 11 (Near lake area)	4.82	Basin 1 (Perry Cr)	1.19
Basin 8 (Upper French Cr)	4.74	Basin 11 (Near lake area)	1.18
Basin 5 (Lower N. Cottonwood R)	4.63	Basin 5 (Lower N. Cottonwood R)	1.13
Basin 3 (Middle N. Cottonwood R)	4.37	Basin 3 (Middle N. Cottonwood R)	1.13
Basin 6 (Dry Creek)	4.07	Basin 2 (Middle N Cottonwood R)	1.06
Basin 2 (Middle N Cottonwood R)	3.95	Basin 6 (Dry Creek)	1.01
Basin 7 (Upper N. Cottonwood R)	2.86	Basin 7 (Upper N. Cottonwood R)	0.70

Marion Lake was segmented into four sections (Riverine, transitional, main basin, and cove areas), according to lake morphological characteristics, and then modeled using BATHTUB (**Figure 18**). Atmospheric N input data was obtained from National Atmospheric Deposition Program/National Trend Network while P deposition rate data was estimated using the 1983 study of Rast and Lee. Water quality data for the main basin segment was averaged using the 1996-2005 data from the KDHE and U.S. Corps of Engineers, Tulsa District Office whereas water quality data for the riverine and transitional segments were directly derived from the 2004-2005 lake data collected by the U.S. Corps of Engineers, Tulsa District Office. Watershed nutrient loading data was provided from the calibrated/validated GWLF model. The BATHTUB setting and nutrient model selections are provided in **Appendix C**. The internal loading though an important nutrient source was not activated in the model because the model was set up for a long-term water quality simulation. The accuracy of model calibration and validation (or goodness of fit) was based on T-statistics for modeled parameters; an appropriate model was selected when there were no significant differences between observed and predicted means of the target variables (BATHTUB manual).

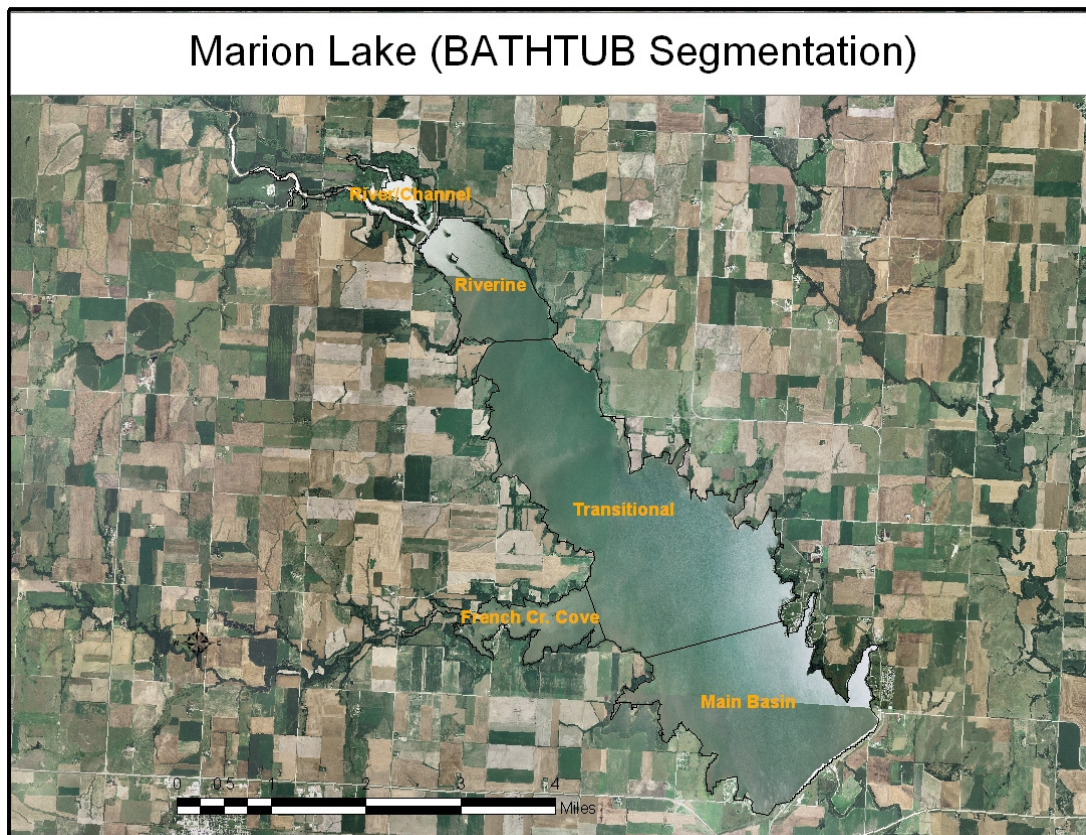


Figure 18. BATHTUB segments (riverine, transitional, and main basin areas).

Figure 19 shows the modeling results of calibrated BATHTUB model. In general, the simulated lake condition corresponded well with the observed condition for each segmented area, with the exception of high TN and TP occurring in the riverine area. The appearance of the elevated nutrient levels in the riverine area was associated with spring algal blooms in 2004. BATHTUB

estimated that approximately 79% of TN and 93% of TP were retained annually by the lake while 21% of TN and 7% of TP exited the reservoir through outflow. For Marion Lake, annual atmospheric deposition contributed about 19.41 metric tons and 0.27 metric tons of TN and TP, respectively.

Marion Lake is designated as a Class A Primary Contact Recreational Lake. According to the state eutrophication TMDLs (<http://www.kdheks.gov/tmdl/eutro.htm>), 12 µg/L of Chla has been targeted for primary contact recreational lakes (i.e., swimming) whereas the 20 µg/L of Chla is implemented for secondary contact recreation lakes (i.e., fishing). However, with the public water supply use in the future, an ultimate target of average Chla concentrations of 10 µg/L should be attained. Based on the modeling results, a 70% nutrient (TN and TP) reduction from the watershed is required to reach the interim endpoint at the main basin area as opposed to approximately 85% of TP reduction when TN reductions are not considered (**Figure 20**). Because Marion Lake is a N-limited lake, Load Allocations are determined, based on TN and TP, instead of TP only. For the final TMDL endpoint, an 80% nutrient (TN and TP) reduction from the watershed is required. Thus, the load capacity for Marion Lake will be initially 173,742 lbs/yr for TN and 44,438 lbs/yr for TP. The ultimate load capacity to achieve 10 µg/L of Chla will be 115,824 lbs/yr for TN and 29,619 lbs/yr for TP.

Marion Lake (BATHTUB Modeling)

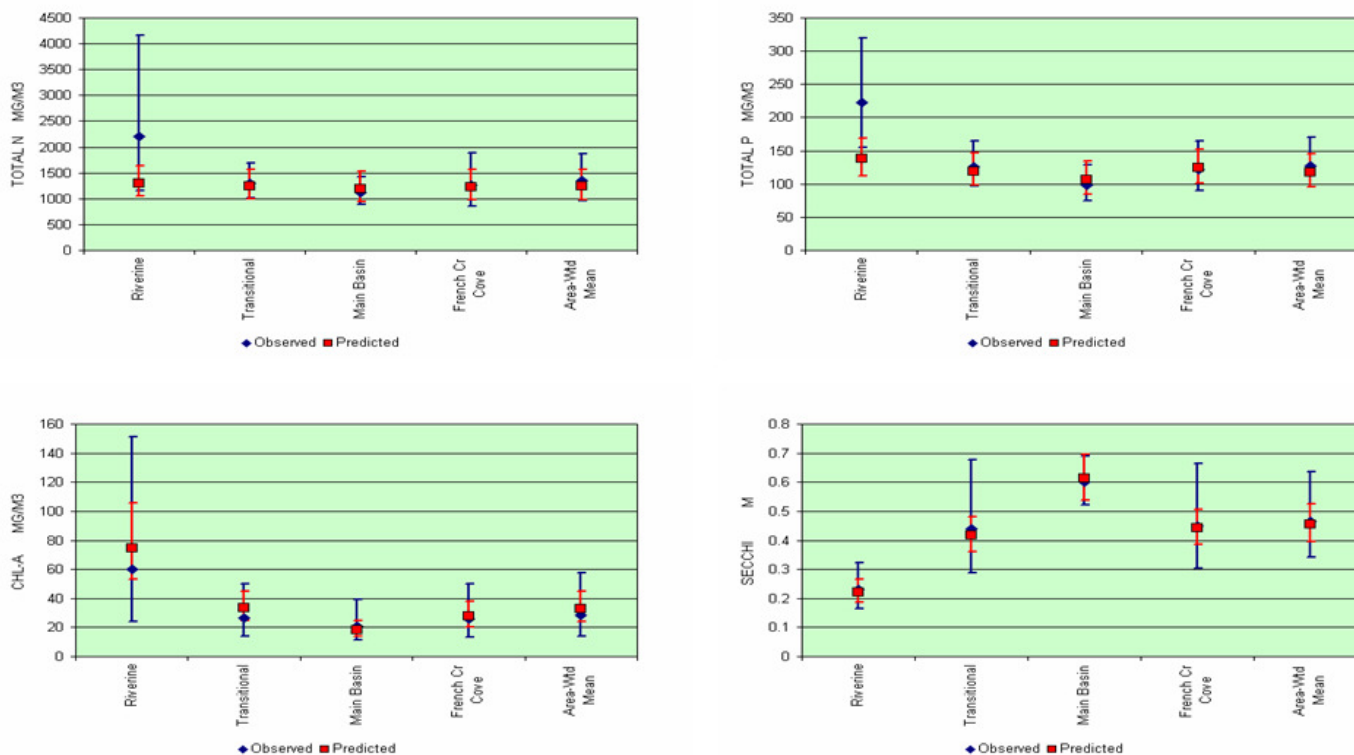


Figure 19. Error bar plots (mean \pm standard deviation) of TN, TP, Chla, and Secchi depth parameters estimated by BATHTUB model for the current conditions at Marion Lake.

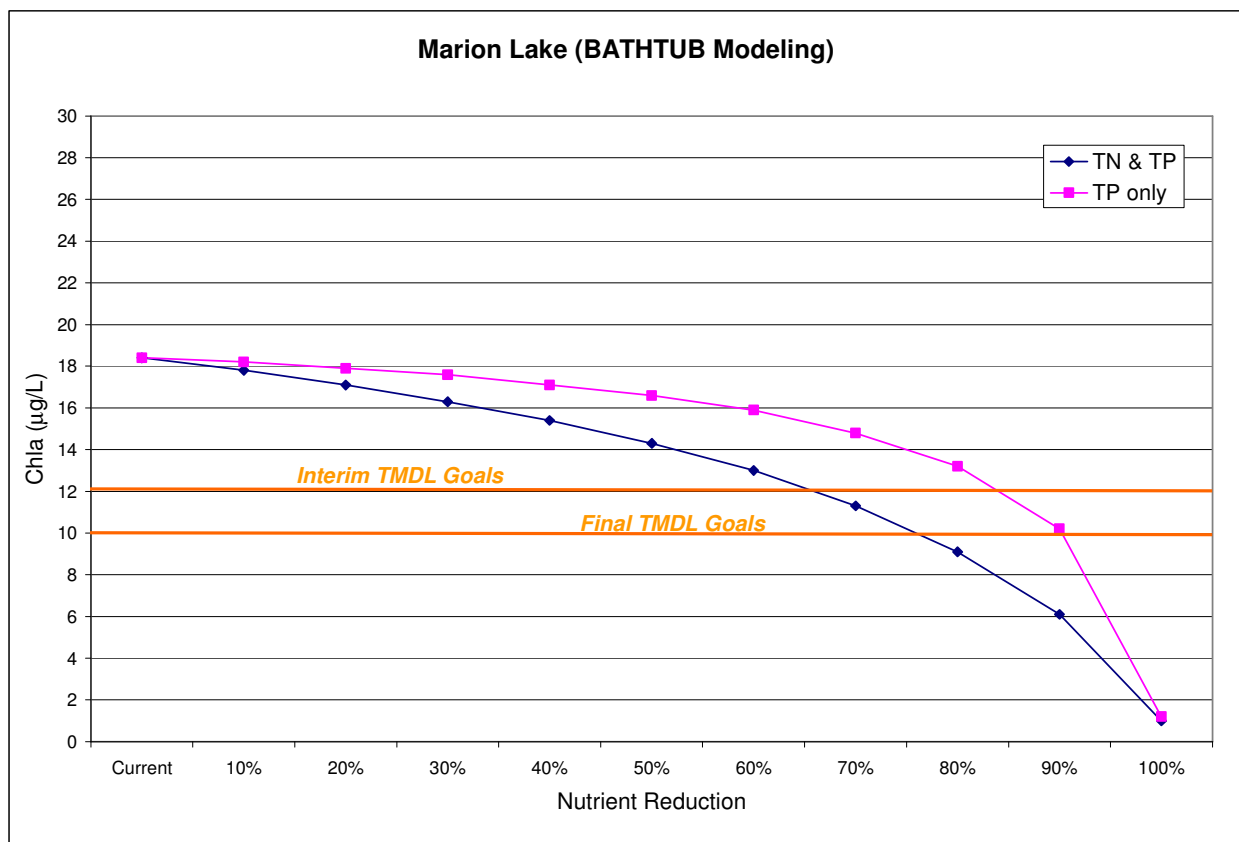


Figure 20. Changes in Chla levels in relation to nutrient loading reduction from the watershed.

Point Sources: This allocation is associated with the Waste Treatment Plants. Ongoing inspections and monitoring of these NPDES sites will be made to ascertain the contributions that have been made by the source. These Waste Treatment Plants should comply with any future permit conditions. The Wasteload Allocation should be at 3,183 lbs of TN and 909 lbs of TP per year, based on expected average nutrient concentrations in wastewater lagoon effluent (7 mg/L of TN and 2 mg/L of TP). As previously noted in the inventory and assessment section, the non-discharging permitted municipal facility waste management systems located within the watershed does not discharge with sufficient frequency or duration to add to impairment in the lake. Therefore, the Wasteload Allocation for Durham MWTP and Marion Co. SD#1 are set to 0 lbs per year for both TN and TP. Wasteload allocations for these facilities are listed in **Appendix D**. Elimination of the wastewater discharge from Canton and Lehigh will reduce nutrient loads and Chla concentration by only 2%.

Nonpoint Sources: Degraded water quality is closely associated with excess nutrient loading that comes predominantly from nonpoint pollution sources. The source assessment suggests that cropland and animal waste contribute to elevated Chla concentrations in the lake. Frequent undesired algal blooms are directly connected to the nutrient patterns (decreased TN and increased TP levels) in the lake. To manage Chla levels to the desirable interim endpoint, 70% nutrient reduction from the watershed is necessary. Therefore, Load Allocations for the

watershed are set to 153,185 lbs of TN and 39,086 lbs of TP per year. For the final endpoint, 80% nutrient reduction is needed and therefore, Load Allocations for the watershed are set to 101,059 lbs of TN and 25,748 lbs of TP per year (**Table 11**). Daily loads of TN and TP, required by EPA Region VII, are calculated in **Appendix E** (USEPA, 1991).

BATHTUB model indicates that the majority of the nutrients are trapped as sediments accumulated in the lake bottom. Although sediments often function as a nutrient sink, they may act as an important nutrient source if the lake undergoes extensive DO stratification. According to the 2007 nutrient regeneration study conducted by the KBS, the levels of TP released from the sediments can sufficiently support algal growth. This implies that when the nutrient loading is reduced from the watershed, the improvement in water quality may be delayed because of the internal nutrient loading from the lake bottom.

Defined Margin of Safety: The margin of safety is explicit and provides some hedge against the uncertainty of annual allocated nutrient loads in reaching the chlorophyll *a* endpoint. Therefore, the margin of safety, 10% of the total nutrient loads from the watershed, will be 17,374 lbs of TN and 4,443 lbs per year of TP for the interim TMDL goals, and 11,582 lbs of TN and 2,962 lbs per year of TP for the final TMDL goals.

Table 11. TMDL Waste Load and Load Allocations for 12 µg/L and 10 µg/L of Chla levels.

	WLA	LA (Chla=12)	LA (Chla=10)	MOS (Chla=12)	MOS (Chla=10)	TMDL (Chla=12)	TMDL (Chla=10)
TN (lbs/yr)	3,183	153,185	101,059	17,374	11,582	173,742	115,824
TP (lbs/yr)	909	39,086	25,748	4,443	2,962	44,438	29,619

State Water Plan Implementation Priority: Because Marion Lake is a federal reservoir with a relatively large watershed and a large regional benefit for recreation and state invested water supply, this TMDL will be a High Priority for implementation.

Unified Watershed Assessment Priority Ranking: This watershed lies within the Upper Cottonwood (HUC 8: 11070202) with a priority ranking of 36 (Medium Priority for restoration).

Priority HUC 11s: Implementation should concentrate on the watersheds of Silver Creek, French Creek, Perry Creek, the North Cottonwood Rive above Durham, and the lands that surround Marion Lake.

5. IMPLEMENTATION

Desired Implementation Activities

There is a good potential that agricultural best management practices will improve the water quality in Marion Lake. Some of the recommended agricultural practices are as follows:

1. Perform soil tests and apply nutrient best management practices (BMPs) to reduce nutrient additions to the lake from excess fertilization,
2. Maintain conservation tillage and contour farming to minimize cropland erosion,
3. Promote and adopt continuous no-till cultivation to increase the amount of water infiltration and minimize cropland soil erosion and nutrient transports,

4. Install grass buffer strips along streams,
5. Reduce activities within riparian areas,
6. Reduce both confined and non-confined animal feeding operation sites,
7. Evaluate a lake application of chelating agents to bond phosphorus to sediments,
8. Construct ponds/detention basins, erosion control structures and/or wetlands to reduce soil erosion and to trap sediment and lower peak runoff rates.

Implementation Programs Guidance

NPDES-KDHE

- a. Evaluate nutrient loading from all permitted dischargers in the watershed,
- b. Work with dischargers to reducing individual loadings.

Nonpoint Source Pollution Technical Assistance - KDHE

- a. Support Section 319 demonstration projects for reduction of sediment runoff from agricultural activities as well as nutrient management,
- b. Provide technical assistance on practices geared to establishment of vegetative buffer strips,
- c. Provide technical assistance on nutrient management in vicinity of streams,
- d. Support Watershed Restoration and Protection Strategy (WRAPS) efforts for Marion Lake,
- e. Incorporate the provisions of this TMDL into any Marion Lake's WRAPS documents.

Water Resource Cost Share Nonpoint Source Pollution Control Program - SCC

- a. Apply conservation farming practices, including terraces and waterways, sediment control basins, and constructed wetlands,
- b. Provide sediment control practices to minimize erosion and sediment and nutrient transport.

Riparian Protection Program - SCC

- a. Establish or re-establish natural riparian systems, including vegetative filter strips and streambank vegetation,
- b. Develop riparian restoration projects,
- c. Promote wetland construction to assimilate nutrient loadings.

Buffer Initiative Program - SCC

- a. Install grass buffer strips near streams,
- b. Leverage Conservation Reserve Enhancement Program to hold riparian land out of production.

Extension Outreach and Technical Assistance - Kansas State University

- a. Educate agricultural producers on sediment, nutrient, and pasture management,
- b. Educate livestock producers on livestock waste management and manure applications and nutrient management planning,
- c. Provide technical assistance on livestock waste management systems and nutrient management plans,
- d. Provide technical assistance on buffer strip design and minimizing cropland runoff,

- e. Encourage annual soil testing to determine capacity of field to hold nutrients.
- f. Support outreach efforts by Marion Lake WRAPS.

Time Frame for Implementation: Pollutant reduction practices should be installed within the priority subwatersheds before 2012, with follow-up implementation, including other subwatersheds over 2012 – 2016. Achievement of the 12 µg/L of Chla goal is set for 2014. After this goal is reached, implementation of further point and non-point source control should be made so 10 µg/L of Chla is achieved in 2016.

Targeted Participants: Primary participants for implementation will be agricultural producers within the drainage of the lake. Initial work before 2011 should include local assessments by conservation district personnel and county extension agents to locate within the lake drainage:

1. Total row crop acreage and fertilizer application rate,
2. Cultivation alongside lake,
3. Drainage alongside or through animal feeding lots,
4. Livestock use of riparian areas,
5. Fields with manure applications.

Milestone for 2012: The year 2012 marks the midpoint of the ten-year implementation window for the watershed. At that point in time, sampled data from Marion Lake should indicate evidence of reduced phosphorus levels in the conservation pool elevations relative to the conditions seen over 1987-2004.

Delivery Agents: The primary delivery agents for program participation will be conservation districts for programs of the State Conservation Commission and the Natural Resources Conservation Service. Producer outreach and awareness will be delivered by Kansas State Extension and Marion Lake WRAPS. Implementation decisions and scheduling will be guided by planning documents prepared through Marion Lake WRAPS.

Reasonable Assurances:

Authorities: The following authorities may be used to direct activities in the watershed to reduce pollution.

1. K.S.A. 65-164 and 165 empowers the Secretary of KDHE to regulate the discharge of sewage into the waters of the state.
2. K.S.A. 65-171d empowers the Secretary of KDHE to prevent water pollution and to protect the beneficial uses of the waters of the state through required treatment of sewage and established water quality standards and to require permits by persons having a potential to discharge pollutants into the waters of the state.
3. K.A.R. 28-16-69 to -71 implements water quality protection by KDHE through the establishment and administration of critical water quality management areas on a watershed basis.

4. K.S.A. 2-1915 empowers the State Conservation Commission to develop programs to assist the protection, conservation and management of soil and water resources in the state, including riparian areas.
5. K.S.A. 75-5657 empowers the State Conservation Commission to provide financial assistance for local project work plans developed to control non-point source pollution.
6. K.S.A. 82a-901, *et seq.* empowers the Kansas Water Office to develop a state water plan directing the protection and maintenance of surface water quality for the waters of the state.
7. K.S.A. 82a-951 creates the State Water Plan Fund to finance the implementation of the *Kansas Water Plan*.
8. The *Kansas Water Plan* and the Neosho River Basin Plan provide the guidance to state agencies to coordinate programs intent on protecting water quality and to target those programs to geographic areas of the state for high priority in implementation.
9. K.S.A. 32-807 authorizes Kansas Department of Wildlife and Parks to manage lake resources.

Funding: The State Water Plan Fund annually generates \$16-18 million and is the primary funding mechanism for implementing water quality protection and pollution reduction activities in the state through the *Kansas Water Plan*. The state water planning process, overseen by the Kansas Water Office, coordinates and directs programs and funding toward watersheds and water resources of highest priority. Typically, the state allocates at least 50% of the fund to programs supporting water quality protection through the WRAPS program. This watershed and its TMDL are a High Priority consideration.

Effectiveness: Nutrient control has been proven effective through conservation tillage, contour farming and use of grass waterways and buffer strips. The key to success will be widespread utilization of conservation farming within the watersheds cited in this TMDL.

6. MONITORING

Future lake sampling should occur at least 3 times between 2008 and 2015. Monitoring of tributary levels of nutrients during runoff events will help direct abatement efforts toward major contributors. Additionally, tracking of nutrient loads from the existing municipal lagoons should be done to confirm their small contribution to the lake.

7. FEEDBACK

Public meetings to discuss TMDLs in the Neosho Basin were held on December 8, 2006 in Columbus, September 27, 2007 in Schermerhorn Nature Center (Galena), February 28 in Burlington at the Coffey County Courthouse and May 15, 2008 in Emporia City Library. An active Internet Web site was established at <http://www.kdhe.state.ks.us/tmdl/> to convey

information to the public on the general establishment of TMDLs and specific TMDLs for the Neosho Basin.

Public Hearing: Public Hearings on the TMDL of the Neosho Basin were held in Burlington at the Coffey County Courthouse on July 24, 2008.

Discussion with Interest Groups: The staff of Watershed Management Section of KDHE were briefed on the implications of this TMDL on October 22, 2007, and the Marion Lake WRAPS on October 30 and November 14, 2007.

Basin Advisory Committee: The Neosho Basin Advisory Committee met to discuss the TMDLs in the basin on September 27, 2007 in Schermerhorn Nature Center (Galena), February 28 in Burlington at the Coffey County Courthouse and May 15, 2008 in Emporia City Library.

Milestone Evaluation: In 2012, evaluation will be made as to the degree of implementation which has occurred within the watershed and current condition of Marion Lake. Subsequent decisions will be made through the Marion Lake WRAPS, regarding the implementation approach and follow up of additional implementation in the watershed.

Consideration for 303(d) Delisting: The lake will be evaluated for delisting under Section 303(d), based on the monitoring data over the period 2008-2015. Therefore, the decision for delisting will come about in the preparation of the 2016 303(d) list. Should modifications be made to the applicable water quality criteria during the ten-year implementation period, consideration for delisting, desired endpoints of this TMDL and implementation activities may be adjusted accordingly.

Incorporation into Continuing Planning Process, Water Quality Management Plan and the Kansas Water Planning Process: Under the current version of the Continuing Planning Process (CPP), the next anticipated revision will come in 2008 which will emphasize implementation of WRAPS activities. At that time, incorporation of this TMDL will be made into the WRAPS. Recommendations of this TMDL will be considered in *Kansas Water Plan* implementation decisions under the State Water Planning Process after Fiscal Years 2008 – 2015.

Developed, November 21, 2008

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Appendix A. GWLF Input and Setting

Land Use/Land Cover (LULC) Input (all units are in hectare).

Subwatershed	Cropland	Pasture	Grassland	Deciduous Forest	Mixed Forest	E.H. Wetlands	Woody Wetlands	Open Water
Basin 1	1883.26	195.81	1092.44	95.33	0	0	20.51	5.04
Basin 2	1318.27	35.04	1566.37	104.57	0	0	59.70	12.47
Basin 3	1950.56	163.56	2934.64	164.84	0	0	57.89	30.88
Basin 4	2055.82	155.57	2265.97	97.73	0	0.64	69.48	16.00
Basin 5	2041.51	106.78	2130.16	107.63	0	0.83	26.52	33.71
Basin 6	3180.35	79.70	3350.34	396.27	0	0.65	139.40	45.70
Basin 7	398.82	1.47	1681.13	34.21	0	0	9.48	10.96
Basin 8	1925.08	101.95	2623.61	158.98	0	0	55.39	9.74
Basin 9	2039.48	195.82	952.93	114.77	0.99	0	16.24	13.87
Basin 10	2363.77	143.70	953.70	148.26	0.61	0.06	81.30	8.54
Basin 11	4017.01	155.58	1940.85	291.64	1.02	17.84	97.17	9.12

(Note: E.H. Wetland = Emergent Herbaceous Wetlands)

Subwatershed	Developed Open Space	Developed Low Intensity	Developed Medium Intensity	Developed High Intensity	Shrub	Barren
Basin 1	144.66	3.62	0	0	0	0
Basin 2	143.02	0.45	0	0	0	0
Basin 3	212.58	5.81	0	0	0	0
Basin 4	167.29	22.42	0.69	0.02	0	0
Basin 5	153.16	34.42	2.26	1.07	0	0
Basin 6	275.98	30.83	3.39	2.06	1.50	0
Basin 7	63.01	0	0	0	0	0
Basin 8	201.71	30.05	0	0	0	0
Basin 9	139.36	13.66	0	0	0	1.17
Basin 10	196.62	83.76	17.93	3.09	0.43	0
Basin 11	304.45	53.28	1.18	0	3.54	0

Nutrient Runoff for Rural Land Uses

LULC	Dissolved N (mg/L)	Dissolved P (mg/L)
Cropland	2.50	0.260
Grassland	2.60	0.250
Pasture	2.60	0.250
Forest	0.06	0.009
Shrub	0.06	0.009
Wetlands	0.10	0.120
Barren	0.012	0.002

Buildup Rates for Urban/Developed Land Uses

LULC	N (kg/ha-day)	P (kg/ha-day)
Open Space	0.088	0.0098
Low Intensity	0.012	0.0016
Medium Intensity	0.022	0.0039
High Intensity	0.045	0.0078

Sediment Nutrient Concentrations by Land Use

LULC	N (mg/kg)	P (mg/kg)
Sediment	3245	1300

Groundwater Nutrient Concentrations by Land Use

LULC	Dissolved N (mg/L)	Dissolved P (mg/L)
Groundwater	0.41	0.025

Runoff Curve Numbers (RCN), Slope Length-Gradient (topographic) Factor (LS), and Soil Erodibility (K)

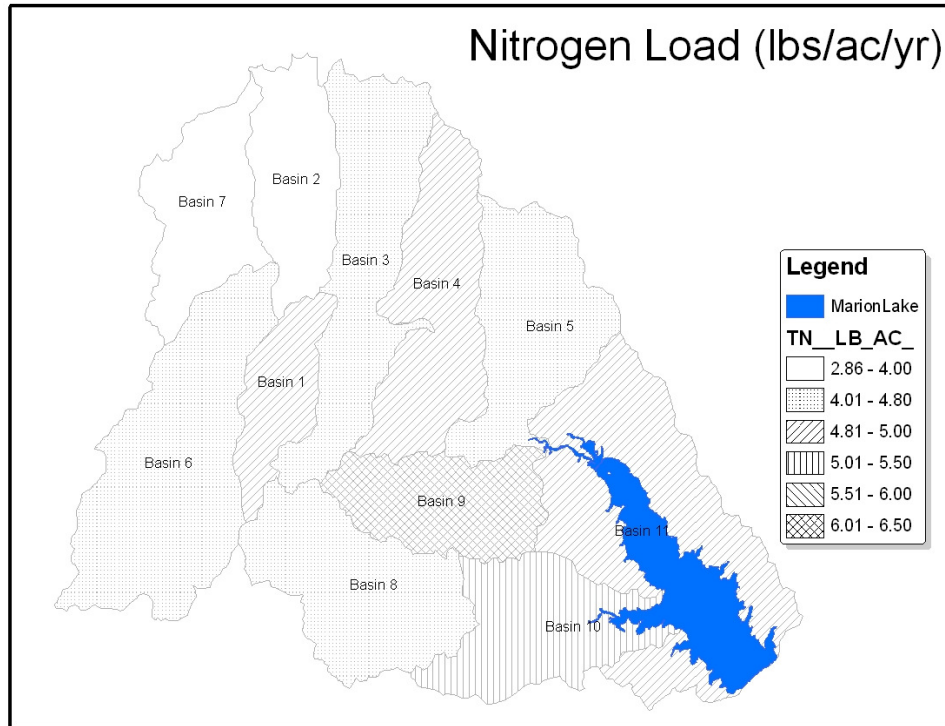
Cropland	RCN	LS	K
Basin 1	86	0.302	0.339
Basin 2	82	0.469	0.313
Basin 3	84	0.515	0.333
Basin 4	84	0.453	0.337
Basin 5	84	0.336	0.352
Basin 6	84	0.399	0.340
Basin 7	82	0.591	0.319
Basin 8	85	0.612	0.347
Basin 9	86	0.433	0.352
Basin 10	84	0.319	0.334
Basin 11	85	0.275	0.357

Evapotranspiration and Rainfall Erosivity

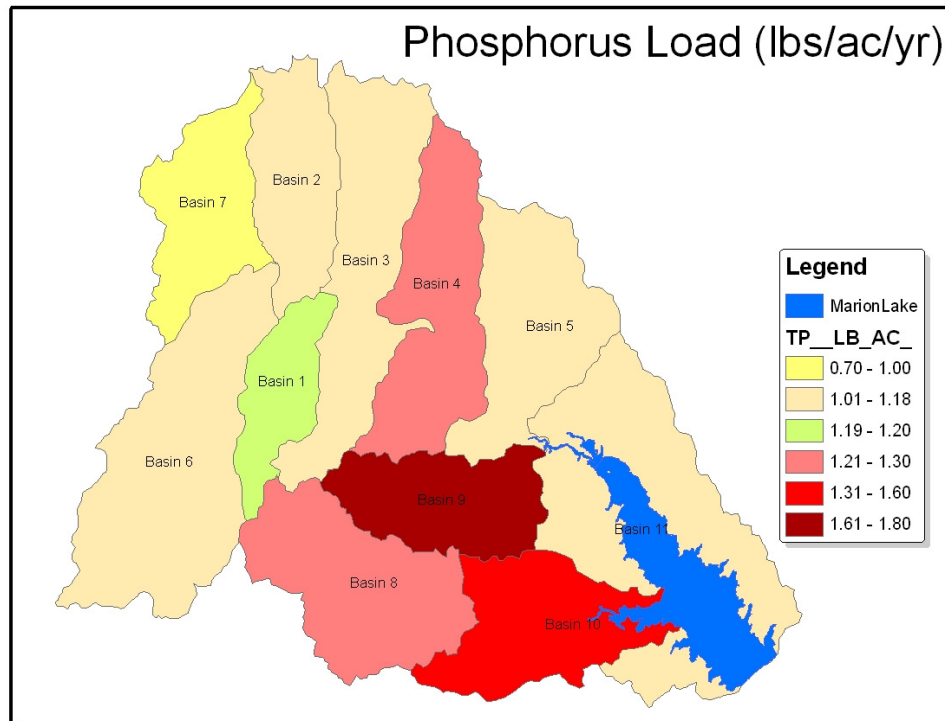
	ET Cover Coefficient	Day Length (hrs)	Growing Season	Erosivity Coefficient
APR	0.65	13.1	0	0.3
MAY	0.9	14.2	1	0.3
JUNE	0.95	14.6	1	0.3
JULY	0.99	14.4	1	0.3
AUG	0.95	13.5	1	0.3
SEPT	0.9	12.2	1	0.3
OCT	0.85	10.9	1	0.3
NOV	0.7	9.8	0	0.3
DEC	0.6	9.4	0	0.155
JAN	0.5	9.6	0	0.155
FEB	0.5	10.5	0	0.155
MAR	0.5	11.8	0	0.155

Appendix B.

Nitrogen Load Distribution (lbs/ac/yr).



Phosphorus Load Distribution (lbs/ac/yr).



Appendix C. BATHTUB Input and Output Files

(1) Data Input and Model Setting (or Parameterization)

Case Data.prn - Notepad

File Edit Format View Help

File:F:\Bathtub_KS_Reservoirs\Marion2updated4.btb

Description:

Global Variables	Mean	CV	Model options	Code	Description
Averaging Period (y)	1	0.0	Conservative Substance	0	NOT COMPUTED
Precipitation (m)	0.7257	0.0	Phosphorus Balance	2	2ND ORDER, DECAY
Evaporation (m)	1.2159	0.0	Nitrogen Balance	2	2ND ORDER, DECAY
Storage Increase (m)	0	0.0	Chlorophyll-a	1	P, N, LIGHT, T
			Secchi Depth	1	VS. CHLA & TURBIDITY
Atmos. Loads (kg/km	Mean	CV	Dispersion	1	FISCHER-NUMERIC
Conserv. Substance	0	0.00	Phosphorus Calibration	1	DECAY RATES
Total P	10	0.50	Nitrogen Calibration	1	DECAY RATES
Total N	730	0.50	Error Analysis	1	MODEL & DATA
Ortho P	10	0.50	Availability Factors	1	USE FOR MODEL 1 ONLY
Inorganic N	730	0.50	Mass-Balance Tables	1	USE ESTIMATED CONCS
			Output Destination	1	NOTEPAD

Segment Morphometry										Internal Loads (mg/m2-day)									
Seg	Name	outflow Segment	Group	Area km2	Depth m	Length km	Mixed Depth Mean	Hypol Depth CV	Non-Algal Turb CV	TP (Conserv. Mean)	ortho P CV	ppHOD (ppb/day) Mean	MOD (ppb/day) CV	Total P Mean	Total N CV	Total P Mean	Total N CV		
1	Riverine	2	1	2.87	0.5	3.06	0.5	0	0	2.54	0	0	0	0	0	0	0		
2	Transitional	3	1	13.95	2.8	6.15	2.8	0	0	1.52	0	0	0	0	0	0	0		
3	Main Basin	0	1	7.9	7.2	2.8	5.8	1.4	0	1.14	0	0	0	0	0	0	0		
4	French Cr Cove	2	2	1.87	2	2.39	2	0	0	1.63	0	0	0	0	0	0	0		

Segment observed water Quality										Internal Loads (mg/m2-day)									
Seg	Conserv	Total P (ppb)	Total N (ppb)	Chl-a (ppb)	Secchi (m)	organic N (ppb)	TP (ppb/day)	ortho P (ppb/day)	ppHOD (ppb/day)	MOD (ppb/day)	Total P (ppb)	Total N (ppb)	Chl-a (ppb)	Secchi (m)	organic N (ppb)	TP (ppb/day)	ortho P (ppb/day)	ppHOD (ppb/day)	MOD (ppb/day)
1	0	223	0.36	2197	0.64	60.26	0.92	0.23	0.34	1884	0.63	198	0.36	0	0	0	0	0	0
2	0	126	0.27	1304	0.26	26.71	0.63	0.44	0.43	999	0.28	87	0.41	0	0	0	0	0	0
3	0	98	0.27	1123	0.24	20.88	0.63	0.6	0.14	809	0.59	50	0.54	0	0	0	0	0	0
4	0	122	0.3	1269	0.4	25.67	0.67	0.45	0.39	937	0.31	68	0.4	0	0	0	0	0	0

Segment calibration Factors										Internal Loads (mg/m2-day)									
Seg	Dispersion Rate	Total P (ppb)	Total N (ppb)	Chl-a (ppb)	Secchi (m)	organic N (ppb)	TP (ppb/day)	ortho P (ppb/day)	ppHOD (ppb/day)	MOD (ppb/day)	Total P (ppb)	Total N (ppb)	Chl-a (ppb)	Secchi (m)	organic N (ppb)	TP (ppb/day)	ortho P (ppb/day)	ppHOD (ppb/day)	MOD (ppb/day)
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	0
2	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	0
3	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	0
4	1	0	2	0	2.4	0	0.7	0	1.05	0	0.92	0	0.9	0	1	0	1	0	0

Tributary Data										Internal Loads (mg/m2-day)									
Trib	Trib Name	Segment	Type	Dr Area km2	Flow (hm3/yr)	Conserv.	Total P (ppb)	Total N (ppb)	ortho P (ppb)	Inorganic N (ppb)	Total P (ppb)	Total N (ppb)	Chl-a (ppb)	Secchi (m)	organic N (ppb)	TP (ppb/day)	ortho P (ppb/day)	ppHOD (ppb/day)	MOD (ppb/day)
1	Trib 1	1	1	417.77	51.44	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	Trib 2	4	1	91.08	11.097	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	outflow	3	4	528.36	40.92	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.950	0.45
Total Nitrogen	2.500	0.55
Chl-a Model	1.300	0.26
Secchi Model	0.980	0.10
Organic N Model	1.200	0.12
TP-OP Model	1.000	0.15
HODV Model	1.000	0.15
MODV Model	1.000	0.22
secchi/Chla Slope (m2/mg)	0.025	0.00
Minimum QS (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

(2) Mass Balance

Overall Balances.prn - Notepad									
File Edit Format View Help									
F:\F:\Bathtub_KS_Reservoirs\Marion2updated4.btb									
Overall Water & Nutrient Balances									
Overall Water Balance									
Trbtype	Seg Name	Area	Flow	Averaging	1.00 years				
1	1	1	Tr1b 1	km2	hm3/yr	(hm3/yr)2	-	m/yr	
2	1	4	Tr1b 2	91.1	11.1	0.00E+00	0.00	0.12	
3	4	3	outFlow	528.4	40.9	0.00E+00	0.00	0.08	
PRECIPITATION									
TRIBUTARY INFLOW									
***TOTAL INFLOW									
GAUGED OUTFLOW									
ADVECTIVE OUTFLOW									
***TOTAL OUTFLOW									
***EVAPORATION									
Overall Mass Balance Based Upon Predicted outflow & Reservoir Concentrations									
Component: TOTAL P									
Trbtype	Seg Name	Load	Load Variance	Conc	Export				
1	1	1	Tr1b 1	kg/yr	%Total	(kg/yr)2	%Total	CV	mg/m3 kg/km2/yr
2	1	4	Tr1b 2	53971.2	79.9%	0.00E+00	0.00	1049.2	129.2
3	4	3	outFlow	13353.1	19.8%	0.00E+00	0.00	1203.3	146.6
PRECIPITATION									
TRIBUTARY INFLOW									
***TOTAL INFLOW									
GAUGED OUTFLOW									
ADVECTIVE OUTFLOW									
***TOTAL OUTFLOW									
***RETENTION									
Overflow Rate (m/yr)									
Hydraulic Resid. Time (yrs)									
Reservoir Conc (mg/m3)									
Nutrient Resid. Time (yr)									
Turnover Ratio									
Retention Coef.									
Overall Mass Balance Based Upon Predicted outflow & Reservoir Concentrations									
Component: TOTAL N									
Trbtype	Seg Name	Load	Load Variance	Conc	Export				
1	1	1	Tr1b 1	kg/yr	%Total	(kg/yr)2	%Total	CV	mg/m3 kg/km2/yr
2	1	4	Tr1b 2	213244.7	75.4%	0.00E+00	0.00	4145.5	510.4
3	4	3	outFlow	49992.2	17.7%	0.00E+00	0.00	4505.0	548.9
PRECIPITATION									
TRIBUTARY INFLOW									
***TOTAL INFLOW									
GAUGED OUTFLOW									
ADVECTIVE OUTFLOW									
***TOTAL OUTFLOW									
***RETENTION									
Overflow Rate (m/yr)									
Hydraulic Resid. Time (yrs)									
Reservoir Conc (mg/m3)									
Nutrient Resid. Time (yr)									
Turnover Ratio									
Retention Coef.									

(3) Predicted and Observed Values

Diagnostics.prn - Notepad

File Edit Format View Help

Predicted & Observed values Ranked Against CE Model Development Dataset

Segment: 5 Area-wtd Mean

Predicted values---->

Variable

Mean

CV

Rank

Observed values---->

Mean

CV

Rank

TOTAL P MG/M3

118.7

0.20

84.3%

127.9

0.29

86.2%

TOTAL N MG/M3

1245.0

0.23

63.3%

1344.1

0.33

67.7%

C. NUTRIENT MG/M3

72.3

0.19

81.1%

78.5

0.32

85.8%

CHL-A MG/M3

33.1

0.30

94.9%

28.5

0.70

92.6%

SECCHI M

0.5

0.14

12.8%

0.5

0.31

13.4%

ORGANIC N MG/M3

1226.7

0.25

96.9%

1033.7

0.42

93.7%

TP-ORTHO-P MG/M3

90.4

0.25

87.7%

86.7

0.42

86.8%

ANTIOLOG PC-1

1727.5

0.38

93.2%

1605.0

0.31

92.4%

ANTIOLOG PC-2

7.9

0.17

65.0%

7.1

0.31

57.7%

(N - 150) / P

9.3

0.34

18.6%

9.4

0.25

19.2%

INORGANIC N / P

3.1

2.10

1.1%

7.8

1.70

9.0%

TURBIDITY 1/M

1.5

85.2%

1.5

85.2%

ZMIX * TURBIDITY

4.6

68.4%

4.6

68.4%

ZMIX / SECCHI

6.9

0.14

73.8%

6.8

0.22

72.5%

CHL-A * SECCHI

13.3

0.22

94.7%

12.2

0.45

60.0%

CHL-A / TOTAL P

0.3

0.33

69.6%

0.2

0.42

56.8%

FREQ(CHL-a>10) %

89.3

0.08

94.9%

88.2

0.14

92.6%

FREQ(CHL-a>20) %

61.0

0.23

94.9%

55.3

0.43

92.6%

FREQ(CHL-a>30) %

39.4

0.39

94.9%

32.3

0.65

92.6%

FREQ(CHL-a>40) %

25.7

0.49

94.9%

19.4

0.81

92.6%

FREQ(CHL-a>50) %

17.3

0.58

94.9%

12.1

0.95

92.6%

FREQ(CHL-a>60) %

12.0

0.65

94.9%

7.9

1.10

92.6%

CARLSON TSI-P

73.0

0.04

84.3%

73.7

0.03

86.2%

CARLSON TSI-CHLA

64.0

0.04

94.9%

62.9

0.06

92.6%

CARLSON TSI-SEC

71.9

0.03

87.2%

71.5

0.05

86.6%

Segment: 1 Riverine

Predicted values---->

Variable

Mean

CV

Rank

Observed values---->

Mean

CV

Rank

TOTAL P MG/M3

138.5

0.21

88.1%

223.0

0.36

95.6%

TOTAL N MG/M3

1311.9

0.23

66.2%

2197.0

0.64

89.0%

C. NUTRIENT MG/M3

79.4

0.19

84.1%

135.5

0.52

25.2%

CHL-A MG/M3

75.5

0.34

99.7%

60.3

0.92

99.2%

SECCHI M

0.2

0.18

1.9%

0.2

0.34

2.1%

ORGANIC N MG/M3

2482.3

0.31

99.9%

1884.0

0.63

99.7%

TP-ORTHO-P MG/M3

190.4

0.28

97.4%

198.0

0.36

97.7%

ANTIOLOG PC-1

4751.6

0.44

98.8%

5097.2

0.65

99.0%

ANTIOLOG PC-2

10.3

0.17

81.3%

7.7

0.69

63.7%

(N - 150) / P

8.4

0.31

15.0%

9.2

0.77

18.3%

INORGANIC N / P

1.0

0.0%

12.5

7.41

19.2%

TURBIDITY 1/M

2.5

94.8%

2.5

94.8%

ZMIX * TURBIDITY

1.3

12.1%

1.3

12.1%

ZMIX / SECCHI

2.3

0.17

9.9%

2.2

0.33

8.8%

CHL-A * SECCHI

16.7

0.22

75.7%

13.9

0.98

66.8%

CHL-A / TOTAL P

0.5

0.34

94.6%

0.3

0.98

69.3%

FREQ(CHL-a>10) %

99.8

0.00

99.7%

99.5

0.02

99.2%

FREQ(CHL-a>20) %

96.6

0.04

99.7%

92.9

0.21

99.2%

FREQ(CHL-a>30) %

88.1

0.12

99.7%

79.2

0.52

99.2%

FREQ(CHL-a>40) %

76.2

0.22

99.7%

63.7

0.85

99.2%

FREQ(CHL-a>50) %

63.8

0.32

99.7%

49.6

1.19

99.2%

FREQ(CHL-a>60) %

52.4

0.42

99.7%

38.1

1.47

99.2%

CARLSON TSI-P

75.3

0.04

88.1%

82.1

0.06

95.6%

CARLSON TSI-CHLA

73.0

0.03

99.7%

70.8

0.13

99.2%

CARLSON TSI-SEC

81.7

0.03

98.1%

81.2

0.06

97.9%

Segment: 2 Transitional

Predicted values---->

Variable

Mean

CV

Rank

Observed values---->

Mean

CV

Rank

TOTAL P MG/M3

120.5

0.20

84.7%

128.0

0.27

85.9%

TOTAL N MG/M3

1254.4

0.23

63.7%

1304.0

0.26

66.0%

C. NUTRIENT MG/M3

73.1

0.18

81.5%

76.4

0.26

82.9%

CHL-A MG/M3

33.4

0.30

95.0%

26.7

0.63

91.3%

SECCHI M

0.4

0.14

10.5%

0.4

0.43

11.9%

ORGANIC N MG/M3

1240.7

0.23

97.0%

999.0

0.28

92.8%

TP-ORTHO-P MG/M3

91.4

0.23

88.0%

87.0

0.41

86.9%

ANTIOLOG PC-1

1669.1

0.36

92.8%

1362.1

0.44

90.5%

ANTIOLOG PC-2

8.2

0.17

67.5%

6.9

0.52

55.8%

(N - 150) / P

9.2

0.33

18.2%

9.2

0.39

18.2%

Segment: 3 Main Basin

Predicted values---->

Variable

Mean

CV

Rank

Observed values---->

Mean

CV

Rank

TOTAL P MG/M3

106.9

0.23

81.4%

98.0

0.27

78.7%

TOTAL N MG/M3

1206.0

0.24

61.4%

1123.0

0.24

57.1%

C. NUTRIENT MG/M3

67.9

0.19

78.9%

62.5

0.25

75.8%

CHL-A MG/M3

18.4

0.28

81.0%

20.9

0.63

85.0%

SECCHI M

0.6

0.13

22.7%

0.6

0.14

22.0%

ORGANIC N MG/M3

796.0

0.22

84.5%

809.0

0.59

85.3%

TP-ORTHO-P MG/M3

55.7

0.22

74.3%

50.0

0.54

70.5%

ANTIOLOG PC-1

816.4

0.33

82.1%

845.5

0.44

82.8%

ANTIOLOG PC-2

6.6

0.17

52.5%

7.3

0.46

59.4%

(N - 150) / P

9.9

0.36

21.3%

9.9

0.38

21.5%

INORGANIC N / P

8.0

0.90

9.4%

6.5

1.91

6.4%

TURBIDITY 1/M

1.1

76.2%

1.1

76.2%

ZMIX * TURBIDITY

6.6

83.0%

6.6

83.0%

ZMIX / SECCHI

9.5

0.13

88.1%

9.7

0.14

88.8%

CHL-A * SECCHI

11.3

0.22

55.7%

12.5

0.65

61.4%

CHL-A / TOTAL P

0.2

0.33

42.1%

0.2

0.68

55.2%

FREQ(CHL-a>10) %

75.1

0.10

81.0%

81.0

0.33

85.0%

FREQ(CHL-a>20) %

33.0

0.50

82.0%

40.5

0.96

85.0%

FREQ(CHL-a>30) %

13.7

0.74

81.0%

18.5

1.47

85.0%

FREQ(CHL-a>40) %

6.0

0.92

81.0%

8.7

1.88

85.0%

FREQ(CHL-a>50) %

2.8

1.08

81.0%

4.3

2.22

85.0%

FREQ(CHL-a>60) %

1.3

1.21

81.0%

2.2

2.50

85.0%

CARLSON TSI-P

71.5

0.05

81.4%

70.3

0.05

78.7%

CARLSON TSI-CHLA

59.2

0.05

81.0%

60.4

0.10

85.0%

CARLSON TSI-SEC

67.1

0.03

77.3%

67.4

0.03

78.0%

Segment: 4 French Cr Cove

Predicted values---->

Variable

Mean

CV

Rank

Observed values---->

Mean

CV

Rank

TOTAL P MG/M3

124.8

0.20

85.6%

122.0

0.30

85.1%

TOTAL N MG/M3

1237.7

0.23

62.9%

1269.0

0.40

64.4%

C. NUTRIENT MG/M3

73.3

0.19

81.6%

74.1

0.36

81.9%

CHL-A MG/M3

28.0

0.31

92.2%

25.7

0.67

90.4%

SECCHI M

0.4

0.14

12.0%

0.4

0.39

12.5%

ORGANIC N MG/M3

1014.4

0.25

93.2%

937.0

0.31

90.9%

TP-ORTHO-P MG/M3

76.0

0.24

83.6%

68.0

0.40

80.5%

ANTIOLOG PC-1

1371.0

0.37

90.6%

1265.1

0.47

89.5%

ANTIOLOG PC-2

7.3

0.18

59.3%

6.8

0.54

54.6%

(N - 150) / P

8.7

0.34

16.3%

9.2

0.54

18.2%

INORGANIC N / P

4.6

1.44

3.0%

6.1

1.94

5.7%

TURBIDITY 1/M

1.6

86.8%

1.6

86.8%

ZMIX * TURBIDITY

3.3

88.1%

3.3

88.1%

ZMIX / SECCHI

4.5

0.13

46.5%

4.4

0.38

45.2%

CHL-A * SECCHI

12.4

0.24

60.8%

11.6

0.78

57.0%

CHL-A / TOTAL P

0.2

0.33

58.5%

0.2

0.73

54.4%

FREQ(CHL-a>10) %

91.2

0.08

92.2%

88.7

0.22

90.4%

FREQ(CHL-a>20) %

59.3

0.32

92.2%

53.7

0.79

90.4%

FREQ(CHL-a>30) %

33.7

0.54

92.2%

28.7

1.28

90.4%

FREQ(CHL-a>40) %

18.8

0.72

92.2%

15.3

1.69

90.4%

FREQ(CHL-a>50) %

10.7

0.87

92.2%

8.3

2.03

90.4%

FREQ(CHL-a>60) %

6.2

0.99

92.2%

4.7

3.32

90.4%

CARLSON TSI-P

73.8

0.04

85.6%

73.4

0.06

85.1%

CARLSON TSI-CHLA

63.3

0.05

92.2%

62.4

0.10

90.4%

CARLSON TSI-SEC

71.8

0.03

88.0%

71.5

0.08

87.5%

(4) Calibration/Validation

T tests.prn - Notepad

File Edit Format View Help

File: F:\bathtub_KS_Reservoirs\MarionUpdated4.btb

T Statistics Compare Observed and Predicted Means Using the Following Error Terms:
1 = Observed Water Quality Error only
2 = Error Typical of Model Development dataset
3 = Observed & Predicted Error

Segment: Area-wtd Mean

Variable	Observed Mean	CV	Predicted Mean	CV	Obs/Pre Ratio	T-Statistics ---->		
						T1	T2	T3
TOTAL P MG/M3	127.9	0.29	118.7	0.20	1.08	0.26	0.28	0.21
TOTAL N MG/M3	1344.1	0.33	1245.0	0.23	1.08	0.23	0.35	0.19
C. NUTRIENT MG/M3	78.5	0.35	72.3	0.19	1.09	0.26	0.41	0.23
CHL-A MG/M3	28.5	0.70	33.1	0.30	0.86	-0.21	-0.43	-0.20
SECCCHI M	0.5	0.31	0.5	0.14	1.02	0.07	0.08	0.07
ORGANIC N MG/M3	1033.7	0.42	1226.7	0.25	0.84	-0.40	-0.68	-0.35
TP-ORTHO-P MG/M3	86.7	0.42	90.4	0.25	0.96	-0.10	-0.12	-0.09
ANTILOG PC-1	1605.0	0.31	1727.5	0.38	0.93	-0.24	-0.21	-0.15
ANTILOG PC-2	7.1	0.31	7.9	0.17	0.90	-0.32	-0.32	-0.28
(N = 150) / P	9.4	0.25	9.3	0.34	1.01	0.06	0.04	0.03

Segment: 1 Riverine

Variable	Observed Mean	CV	Predicted Mean	CV	Obs/Pre Ratio	T-Statistics ---->		
						T1	T2	T3
TOTAL P MG/M3	223.0	0.36	138.5	0.21	1.61	1.32	1.77	1.15
TOTAL N MG/M3	2197.0	0.64	1311.9	0.22	1.67	0.81	2.34	0.76
C. NUTRIENT MG/M3	135.5	0.52	79.4	0.19	1.71	1.03	2.66	0.97
CHL-A MG/M3	60.3	0.92	75.5	0.34	0.80	-0.24	-0.65	-0.23
SECCCHI M	0.2	0.34	0.2	0.18	1.04	0.11	0.14	0.10
ORGANIC N MG/M3	1884.0	0.63	2482.3	0.31	0.76	-0.44	-1.10	-0.39
TP-ORTHO-P MG/M3	198.0	0.36	190.4	0.28	1.04	0.11	0.11	0.09
ANTILOG PC-1	5097.2	0.65	4751.6	0.44	1.07	0.11	0.20	0.09
ANTILOG PC-2	7.7	0.69	10.3	0.17	0.75	-0.41	-0.91	-0.40
(N = 150) / P	9.2	0.77	8.4	0.31	1.09	0.12	0.28	0.11

Segment: 2 Transitional

Variable	Observed Mean	CV	Predicted Mean	CV	Obs/Pre Ratio	T-Statistics ---->		
						T1	T2	T3
TOTAL P MG/M3	126.0	0.27	120.5	0.20	1.05	0.16	0.17	0.13
TOTAL N MG/M3	1304.0	0.26	1254.4	0.23	1.04	0.15	0.18	0.11
C. NUTRIENT MG/M3	76.4	0.26	73.1	0.18	1.05	0.17	0.22	0.14
CHL-A MG/M3	26.7	0.63	33.4	0.30	0.80	-0.36	-0.65	-0.32
SECCCHI M	0.4	0.43	0.4	0.14	1.06	0.13	0.20	0.12
ORGANIC N MG/M3	999.0	0.28	1240.7	0.25	0.81	-0.77	-0.87	-0.58
TP-ORTHO-P MG/M3	87.0	0.41	91.4	0.25	0.95	-0.12	-0.14	-0.10
ANTILOG PC-1	1362.1	0.44	1669.1	0.36	0.82	-0.46	-0.58	-0.36
ANTILOG PC-2	6.9	0.52	8.2	0.17	0.85	-0.31	-0.52	-0.29
(N = 150) / P	9.2	0.39	9.2	0.33	1.00	0.00	0.00	0.00

Segment: 3 Main Basin

Variable	Observed Mean	CV	Predicted Mean	CV	Obs/Pre Ratio	T-Statistics ---->		
						T1	T2	T3
TOTAL P MG/M3	98.0	0.27	106.9	0.23	0.92	-0.32	-0.32	-0.25
TOTAL N MG/M3	1123.0	0.24	1206.0	0.24	0.93	-0.30	-0.32	-0.21
C. NUTRIENT MG/M3	62.5	0.25	67.9	0.19	0.92	-0.33	-0.42	-0.26
CHL-A MG/M3	20.9	0.63	18.4	0.28	1.13	0.20	0.36	0.18
SECCCHI M	0.6	0.14	0.6	0.13	0.98	-0.14	-0.07	-0.10
ORGANIC N MG/M3	809.0	0.59	796.0	0.22	1.02	0.03	0.06	0.03
TP-ORTHO-P MG/M3	50.0	0.54	55.7	0.22	0.90	-0.20	-0.30	-0.19
ANTILOG PC-1	845.5	0.44	816.4	0.33	1.04	0.08	0.10	0.06
ANTILOG PC-2	7.3	0.46	6.6	0.17	1.10	0.20	0.30	0.19
(N = 150) / P	9.9	0.38	9.9	0.36	1.00	0.01	0.02	0.01

Segment: 4 French Cr Cove

Variable	Observed Mean	CV	Predicted Mean	CV	Obs/Pre Ratio	T-Statistics ---->		
						T1	T2	T3
TOTAL P MG/M3	122.0	0.30	124.8	0.20	0.98	-0.08	-0.08	-0.06
TOTAL N MG/M3	1269.0	0.40	1237.7	0.23	1.03	0.06	0.11	0.05
C. NUTRIENT MG/M3	74.1	0.36	73.3	0.19	1.01	0.03	0.05	0.03
CHL-A MG/M3	25.7	0.67	28.0	0.31	0.92	-0.13	-0.25	-0.12
SECCCHI M	0.4	0.39	0.4	0.14	1.02	0.05	0.07	0.05
ORGANIC N MG/M3	937.0	0.31	1014.4	0.25	0.92	-0.26	-0.32	-0.20

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2 = Error Typical of Model development dataset
3 = Observed & Predicted Error

Segment: Area-wtd Mean

Variable	Observed Mean	CV	Predicted Mean	CV	Obs/Pre Ratio	T-Statistics ---->		
						T1	T2	T3
TOTAL P MG/M3	127.9	0.29	118.7	0.20	1.08	0.26	0.28	0.21
TOTAL N MG/M3	1344.1	0.33	1245.0	0.23	1.08	0.23	0.35	0.19
C. NUTRIENT MG/M3	78.5	0.35	72.3	0.19	1.09	0.26	0.41	0.23
CHL-A MG/M3	28.5	0.70	33.1	0.30	0.86	-0.21	-0.43	-0.20
SECCCHI M	0.5	0.31	0.5	0.14	1.02	0.07	0.08	0.07
ORGANIC N MG/M3	1033.7	0.42	1226.7	0.25	0.84	-0.40	-0.68	-0.35
TP-ORTHO-P MG/M3	86.7	0.42	90.4	0.25	0.96	-0.10	-0.12	-0.09
ANTILOG PC-1	1605.0	0.31	1727.5	0.38	0.93	-0.24	-0.21	-0.15
ANTILOG PC-2	7.1	0.31	7.9	0.17	0.90	-0.32	-0.32	-0.28
(N = 150) / P	9.4	0.25	9.3	0.34	1.01	0.06	0.04	0.03

Segment: 1 Riverine

Variable	Observed Mean	CV	Predicted Mean	CV	Obs/Pre Ratio	T-Statistics ---->		
						T1	T2	T3
TOTAL P MG/M3	223.0	0.36	138.5	0.21	1.61	1.32	1.77	1.15
TOTAL N MG/M3	2197.0	0.64	1311.9	0.22	1.67	0.81	2.34	0.76
C. NUTRIENT MG/M3	135.5	0.52	79.4	0.19	1.71	1.03	2.66	0.97
CHL-A MG/M3	60.3	0.92	75.5	0.34	0.80	-0.24	-0.65	-0.23
SECCCHI M	0.2	0.34	0.2	0.18	1.04	0.11	0.14	0.10
ORGANIC N MG/M3	1884.0	0.63	2482.3	0.31	0.76	-0.44	-1.10	-0.39
TP-ORTHO-P MG/M3	198.0	0.36	190.4	0.28	1.04	0.11	0.11	0.09
ANTILOG PC-1	5097.2	0.65	4751.6	0.44	1.07	0.11	0.20	0.09
ANTILOG PC-2	7.7	0.69	10.3	0.17	0.75	-0.41	-0.91	-0.40
(N = 150) / P	9.2	0.77	8.4	0.31	1.09	0.12	0.28	0.11

Segment: 2 Transitional

Variable	Observed Mean	CV	Predicted Mean	CV	Obs/Pre Ratio	T-Statistics ---->		
						T1	T2	T3
TOTAL P MG/M3	126.0	0.27	120.5	0.20	1.05	0.16	0.17	0.13
TOTAL N MG/M3	1304.0	0.26	1254.4	0.23	1.04	0.15	0.18	0.11
C. NUTRIENT MG/M3	76.4	0.26	73.1	0.18	1.05	0.17	0.22	0.14
CHL-A MG/M3	26.7	0.63	33.4	0.30	0.80	-0.36	-0.65	-0.32
SECCCHI M	0.4	0.43	0.4	0.14	1.06	0.13	0.20	0.12
ORGANIC N MG/M3	999.0	0.28	1240.7	0.25	0.81	-0.77	-0.87	-0.58
TP-ORTHO-P MG/M3	87.0	0.41	91.4	0.25	0.95	-0.12	-0.14	-0.10
ANTILOG PC-1	1362.1	0.44	1669.1	0.36	0.82	-0.46	-0.58	-0.36
ANTILOG PC-2	6.9	0.52	8.2	0.17	0.85	-0.31	-0.52	-0.29
(N = 150) / P	9.2	0.39	9.2	0.33	1.00	0.00	0.00	0.00

Segment: 3 Main Basin

Variable	Observed Mean	CV	Predicted Mean	CV	Obs/Pre Ratio	T-Statistics ---->		
						T1	T2	T3
TOTAL P MG/M3	98.0	0.27	106.9	0.23	0.92	-0.32	-0.32	-0.25
TOTAL N MG/M3	1123.0	0.24	1206.0	0.24	0.93	-0.30	-0.32	-0.21
C. NUTRIENT MG/M3	62.5	0.25	67.9	0.19	0.92	-0.33	-0.42	-0.26
CHL-A MG/M3	20.9	0.63	18.4	0.28	1.13	0.20	0.36	0.18
SECCCHI M	0.6	0.14	0.6	0.13	0.98	-0.14	-0.07	-0.10
ORGANIC N MG/M3	809.0	0.59	796.0	0.22	1.02	0.03	0.06	0.03
TP-ORTHO-P MG/M3	50.0	0.54	55.7	0.22	0.90	-0.20	-0.30	-0.19
ANTILOG PC-1	845.5	0.44	816.4	0.33	1.04	0.08	0.10	0.06
ANTILOG PC-2	7.3	0.46	6.6	0.17	1.10	0.20	0.30	0.19
(N = 150) / P	9.9	0.38	9.9	0.36	1.00	0.01	0.02	0.01

Segment: 4 French Cr Cove

Variable	Observed Mean	CV	Predicted Mean	CV	Obs/Pre Ratio	T-Statistics ---->		
						T1	T2	T3
TOTAL P MG/M3	122.0	0.30	124.8	0.20	0.98	-0.08	-0.08	-0.06
TOTAL N MG/M3	1269.0	0.40	1237.7	0.23	1.03	0.06	0.11	0.05
C. NUTRIENT MG/M3	74.1	0.36	73.3	0.19	1.01	0.03	0.05	0.03
CHL-A MG/M3	25.7	0.67	28.0	0.31	0.92	-0.13	-0.25	-0.12
SECCCHI M	0.4	0.39	0.4	0.14	1.02	0.05	0.07	0.05
ORGANIC N MG/M3	937.0	0.31	1014.4	0.25	0.92	-0.26	-0.32	-0.20
TP-ORTHO-P MG/M3	68.0	0.40	76.0	0.24	0.89	-0.28	-0.30	-0.24
ANTILOG PC-1	1265.1	0.47	1371.0	0.37	0.92	-0.17	-0.21	-0.19
ANTILOG PC-2	6.8	0.54	7.3	0.18	0.94	-0.12	-0.20	-0.11
(N = 150) / P	9.2	0.54	8.7	0.34	1.05	0.09	0.16	0.08

(5) TMDL Load Reduction (80%)

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Predicted & observed values Ranked Against CE Model Development Dataset

Segment: 5

Area-wtd Mean

Variable	Predicted values---->			Observed values---->		
	Mean	CV	Rank	Mean	CV	Rank
TOTAL P MG/M3	50.2	0.20	52.1%	127.9		86.2%
TOTAL N MG/M3	582.2	0.23	19.8%	1344.1		67.7%
C. NUTRIENT MG/M3	29.3	0.22	40.2%	78.5		83.8%
CHL-A MG/M3	13.4	0.35	67.9%	28.4		92.5%
SECCHI M	0.6	0.12	19.3%	0.5		13.4%
ORGANIC N MG/M3	689.7	0.22	76.9%	1033.7		93.7%
TP-ORTHO-P MG/M3	55.5	0.21	74.2%	86.7		86.8%
ANTIOLOG PC-1	434.8	0.40	66.9%	1601.0		92.4%
ANTIOLOG PC-2	5.6	0.21	39.3%	7.1		57.4%
(N - 150) / P	8.6	0.37	15.9%	9.4		19.2%
INORGANIC N / P	1.6	3.28	0.2%	7.8		9.0%
TURBIDITY 1/M	1.5		85.1%	1.5		85.1%
ZMIX * TURBIDITY	4.6		68.4%	4.6		68.4%
ZMIX / SECCHI	5.7	0.12	61.5%	6.8		72.5%
CHL-A * SECCHI	7.1	0.30	30.1%	12.1		59.7%
CHL-A / TOTAL P	0.3	0.37	68.3%	0.2		56.4%
FREQ(CHL-a>10) %	53.6	0.38	67.9%	88.0		92.5%
FREQ(CHL-a>20) %	17.5	0.77	67.9%	51.0		92.5%
FREQ(CHL-a>30) %	6.4	1.03	67.9%	32.0		92.5%
FREQ(CHL-a>40) %	2.6	1.23	67.9%	19.2		92.5%
FREQ(CHL-a>50) %	1.2	1.39	67.9%	12.0		92.5%
FREQ(CHL-a>60) %	0.6	1.53	67.9%	7.8		92.5%
CARLSON TSI-P	60.6	0.05	52.1%	73.7		86.2%
CARLSON TSI-CHLA	55.7	0.06	67.9%	62.9		92.5%
CARLSON TSI-SEC	68.8	0.02	80.7%	71.5		86.6%

Segment: 1

Segname 1

Variable	Predicted values---->			Observed values---->		
	Mean	CV	Rank	Mean	CV	Rank
TOTAL P MG/M3	53.7	0.19	55.0%	223.0		85.6%
TOTAL N MG/M3	592.6	0.23	20.5%	2197.0		89.0%
C. NUTRIENT MG/M3	30.4	0.22	42.0%	135.5		95.2%
CHL-A MG/M3	23.0	0.38	87.8%	60.3		99.2%
SECCHI M	0.3	0.12	5.2%	0.2		2.1%
ORGANIC N MG/M3	1048.0	0.26	94.0%	1884.0		99.7%
TP-ORTHO-P MG/M3	97.1	0.22	89.2%	198.0		97.7%
ANTIOLOG PC-1	873.5	0.43	83.4%	5097.2		99.0%
ANTIOLOG PC-2	6.1	0.23	45.9%	7.7		63.7%
(N - 150) / P	8.2	0.35	14.3%	9.2		18.3%
INORGANIC N / P	1.0		0.0%	12.5		19.2%
TURBIDITY 1/M	2.5		94.8%	2.5		94.8%
ZMIX * TURBIDITY	1.3		12.1%	1.3		12.1%
ZMIX / SECCHI	1.6	0.12	3.0%	2.2		8.8%
CHL-A * SECCHI	7.2	0.32	31.4%	13.9		66.8%
CHL-A / TOTAL P	0.4	0.39	89.1%	0.3		69.3%
FREQ(CHL-a>10) %	85.0	0.17	87.8%	99.5		99.2%
FREQ(CHL-a>20) %	46.7	0.52	87.8%	92.9		99.2%
FREQ(CHL-a>30) %	23.1	0.81	87.8%	79.2		99.2%
FREQ(CHL-a>40) %	11.5	1.04	87.8%	63.7		99.2%
FREQ(CHL-a>50) %	5.9	1.23	87.8%	49.6		99.2%
FREQ(CHL-a>60) %	3.2	1.39	87.8%	38.1		99.2%
CARLSON TSI-P	61.6	0.04	55.0%	82.1		95.6%
CARLSON TSI-CHLA	61.4	0.06	87.8%	70.8		99.2%
CARLSON TSI-SEC	76.7	0.02	94.8%	81.2		97.9%

Segment: 2

Segname 2

Variable	Predicted values---->			Observed values---->		
	Mean	CV	Rank	Mean	CV	Rank
TOTAL P MG/M3	50.5	0.20	52.3%	126.0		85.9%
TOTAL N MG/M3	584.7	0.23	20.0%	1304.0		66.0%
C. NUTRIENT MG/M3	29.4	0.22	40.5%	76.4		82.9%
CHL-A MG/M3	14.0	0.35	69.8%	26.7		91.3%
SECCHI M	0.5	0.12	17.1%	0.4		11.9%
ORGANIC N MG/M3	708.6	0.23	78.5%	999.0		92.8%
TP-ORTHO-P MG/M3	56.8	0.22	74.9%	87.0		86.9%
ANTIOLOG PC-1	444.1	0.40	67.5%	1362.1		90.5%
ANTIOLOG PC-2	5.8	0.21	41.7%	6.9		55.8%
(N - 150) / P	8.6	0.37	15.9%	9.2		18.2%

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TURBIDITY 1/M

1.5

85.1%

1.5

85.1%

ZMIX * TURBIDITY

4.3

4.3

65.1%

ZMIX / SECCHI

5.3

0.12

57.7%

6.4

69.0%

CHL-A * SECCHI

7.3

0.30

32.1%

11.8

57.9%

CHL-A / TOTAL P

0.3

0.37

70.7%

0.2

54.9%

FREQ(CHL-a>10) %

59.2

0.37

69.8%

89.9

91.3%

FREQ(CHL-a>20) %

18.8

0.82

69.8%

56.2

91.3%

FREQ(CHL-a>30) %

6.2

1.14

69.8%

30.9

91.3%

FREQ(CHL-a>40) %

2.3

1.38

69.8%

16.8

91.3%

FREQ(CHL-a>50) %

0.9

1.57

69.8%

9.3

91.3%

FREQ(CHL-a>60) %

0.4

1.73

69.8%

5.1

91.3%

CARLSON TSI-P

60.7

0.05

52.3%

73.9

85.9%

CARLSON TSI-CHLA

56.5

0.06

69.8%

62.8

91.3%

CARLSON TSI-SEC

69.3

0.02

82.9%

71.8

88.1%

Segment: 3

Segname 3

Variable	Predicted values---->			Observed values---->		
	Mean	CV	Rank	Mean	CV	Rank
TOTAL P MG/M3	47.9	0.21	50.0%	98.0		78.7%
TOTAL N MG/M3	576.7	0.24	19.4%	1123.0		57.1%
C. NUTRIENT MG/M3	28.6	0.22	39.0%	62.5		75.8%
CHL-A MG/M3	9.5	0.33	50.6%	20.9		85.0%
SECCHI M	0.7	0.12	29.1%	0.6		22.0%
ORGANIC N MG/M3	551.5	0.20	61.7%	809.0		85.3%
TP-ORTHO-P MG/M3	39.8	0.21	61.7%	50.0		70.5%
ANTIOLOG PC-1	278.5	0.37	53.9%	845.5		82.8%
ANTIOLOG PC-2	5.2	0.20	34.9%	7.3		59.4%
(N - 150) / P	8.9	0.38	17.1%	9.9		21.5%
INORGANIC N / P	3.1	5.56	1.2%	6.5		6.4%
TURBIDITY 1/M	1.1		76.2%	1.1		76.2%
ZMIX * TURBIDITY	6.6		85.0%	6.6		85.0%
ZMIX / SECCHI	8.2	0.11	82.2%	9.7		88.8%
CHL-A * SECCHI	6.8	0.29	28.1%	12.5		61.4%
CHL-A / TOTAL P	0.2	0.33	50.7%	0.2		51.2%
FREQ(CHL-a>10) %	34.8	0.57	50.6%	81.0		85.0%
FREQ(CHL-a>20) %	6.6	1.06	50.6%	40.5		85.0%
FREQ(CHL-a>30) %	1.5	1.38	50.6%	18.5		85.0%
FREQ(CHL-a>40) %	0.4	1.62	50.6%	8.7		85.0%
FREQ(CHL-a>50) %	0.1	1.81	50.6%	4.3		85.0%
FREQ(CHL-a>60) %	0.1	1.97	50.6%	2.2		85.0%
CARLSON TSI-P	60.0	0.05	50.0%	70.3		78.7%
CARLSON TSI-CHLA	52.7	0.06	50.6%	60.4		85.0%
CARLSON TSI-SEC	64.9	0.03	70.9%	67.4		78.0%

Segment: 4

Segname 4

Variable	Predicted values---->			Observed values---->		
	Mean	CV	Rank	Mean	CV	Rank
TOTAL P MG/M3	52.0	0.19	53.6%	122.0		85.1%
TOTAL N MG/M3	572.6	0.23	19.1%	1269.0		64.4%
C. NUTRIENT MG/M3	29.2	0.22	40.0%	74.1		81.9%
CHL-A MG/M3	10.9	0.36	57.6%	23.6		88.5%
SECCHI M	0.5	0.11	18.2%	0.4		12.5%
ORGANIC N MG/M3	582.6	0.21	65.7%	937.0		90.9%
TP-ORTHO-P MG/M3	48.5	0.20	69.3%	68.0		80.5%
ANTIOLOG PC-1	352.7	0.39	61.0%	1208.3		88.8%
ANTIOLOG PC-2	4.8	0.22	29.0%	6.5		50.3%
(N - 150) / P	8.1	0.37	13.9%	9.2		18.2%
INORGANIC N / P	0.3	5.11	0.0%	6.1		5.7%
TURBIDITY 1/M	1.6		86.8%	1.6		86.8%
ZMIX * TURBIDITY	3.3		51.8%	3.3		51.8%
ZMIX / SECCHI	3.7	0.11	33.1%	4.4		45.2%
CHL-A * SECCHI	5.9	0.33	21.9%	10.6		52.3%
CHL-A / TOTAL P	0.2	0.38	54.1%	0.2		49.3%
FREQ(CHL-a>10) %	43.1	0.53	57.6%	85.9		88.5%
FREQ(CHL-a>20) %	9.8	1.04	57.6%	48.4		88.5%
FREQ(CHL-a>30) %	2.6	1.38	57.6%	24.4		88.5%
FREQ(CHL-a>40) %	0.8	1.64	57.6%	12.3		88.5%
FREQ(CHL-a>50) %	0.3	1.84	57.6%	6.4		88.5%
FREQ(CHL-a>60) %	0.1	2.01	57.6%	3.5		88.5%
CARLSON TSI-P	61.1	0.05	53.6%	73.4		85.1%
CARLSON TSI-CHLA	54.0	0.07	57.6%	61.6		88.5%
CARLSON TSI-SEC	68.9	0.02	81.8%	71.5		87.5%

Appendix D. Wasteload allocation for NPDES and CAFO facilities.

Facility	Permit #	Wasteload Allocation (lbs N/day)	Wasteload Allocation (lbs P/day)
<u>NPDES</u>			
Canton	KS-0098426 (M-NE09-OO01)	6.99	2.00
Durham	KSJ-000350 (M-NE19-NO01)	0.00	0.00
Lehigh	KS-0026417 (M-NE41-OO01)	1.74	0.50
Marion Co. S.D. #1	KSJ-000348 (M-NE45-ND01)	0.00	0.00
<u>CAFO</u>			
Beef (Total head: 700)	A-NEMN-B014	0	0
Beef (500)	A-NEMN-BA22	0	0
Beef (200)	A-NEMN-BA23	0	0
Beef (150)	A-NEMN-BA36	0	0
Beef (50)	A-NEMN-BA44	0	0
Beef (160)	A-NEMN-BA45	0	0
Beef (120)	A-NEMN-BA48	0	0
Beef (300)	A-NEMN-BA49	0	0
Beef (250)	A-NEMN-BA55	0	0
Beef (180)	A-NEMN-BA59	0	0
Beef (200)	A-NEMN-BA63	0	0
Beef (40)	A-NEMN-BA72	0	0
Beef (70)	A-NEMN-BA78	0	0
Beef, Horses, Swine (75)	A-NEMN-BA79	0	0
Beef (600)	A-NEMN-BA83	0	0
Beef (600)	A-NEMN-BA84	0	0
Beef (250)	A-NEMN-BA88	0	0
Beef (400)	A-NEMN-BA89	0	0
Beef (275)	A-NEMN-BA91	0	0
Beef (110)	A-NEMN-BD02	0	0
Dairy (165)	A-NEMN-M006	0	0
Dairy (220)	A-NEMN-M011	0	0
Dairy (95)	A-NEMN-M017	0	0
Dairy (700)	A-NEMN-M020	0	0
Dairy (140)	A-NEMN-M021	0	0
Dairy (355)	A-NEMN-M026	0	0
Dairy (40)	A-NEMN-MA02	0	0
Dairy (30)	A-NEMN-MA08	0	0
Dairy (50)	A-NEMN-MA11	0	0
Dairy (50)	A-NEMN-MA13	0	0
Swine, Beef (1140)	A-NEMN-S008	0	0
Swine (1390)	A-NEMN-S010	0	0
Swine (923)	A-NEMN-S022	0	0
Swine (108)	A-NEMN-SA07	0	0
Swine (125)	A-NEMN-SA08	0	0
Beef (275)	A-NEMP-BA01	0	0
Beef, Horses (520)	A-NEMP-BA02	0	0
Beef (199)	A-NEMP-BA03	0	0

Appendix E.

Conversion to Daily Loads as Regulated by EPA Region VII

The TMDL has estimated an annual average loads for TN and TP that if achieves should meet the water quality targets. A recent court decision often referred to as Anacostia decision have dictated that TMDL include a “daily” load (Friends of the Earth, Inc v. EPA, et al.).

Expressing this TMDL in daily time steps could be misled to imply a daily response to a daily load. It is important to recognize that the growing season mean chlorophyll *a* is affected by many factors such as: internal lake nutrient loading, water residence time, wind action and the interaction between light penetration, nutrients, sediment load and algal response.

To translate long term averages to maximum daily load values, EPA Region 7 has suggested the approach described in the Technical Support Document for Water Quality Based Toxics Control (EPA/505/2-90-001) (TSD).

$$\text{Maximum Daily Load (MDL)} = (\text{Long-Term Average Load}) * e^{[Z\sigma - 0.5\sigma^2]}$$

$$\text{where } \sigma^2 = \ln(CV^2 + 1)$$

CV = Coefficient of Variation = Standard Deviation/Mean
Z = 2.326 for 99th percentile probability basis

Parameter	LTA (NPS)	CV	$e^{[Z\sigma - 0.5\sigma^2]}$	MDL (NPS)
TN (Interim)	153,185 lbs/yr	0.44	2.44	1022.01 lbs/day
TP (Interim)	39,086 lbs/yr	0.40	2.27	243.60 lbs/day
TN (Final)	101,059 lbs/yr	0.44	2.44	674.24 lbs/day
TP (Final)	25,748 lbs/yr	0.40	2.27	160.47 lbs/day

Parameter	LTA (MOS)	CV	$e^{[Z\sigma - 0.5\sigma^2]}$	MOS (TMDL)
TN (Interim)	17,374 Lbs/yr	0.44	2.44	115.92 lbs/day
TP (Interim)	4,443 lbs/yr	0.40	2.27	27.70 lbs/day
TN (Final)	11,582 Lbs/yr	0.44	2.44	77.27 lbs/day
TP (Final)	2,962 lbs/yr	0.40	2.27	18.46 lbs/day